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AUTHOR	Kimbell, Richard
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ABSTRACT

This report seeks to answer a set of related questions in the context of the United Kingdom: where technology education comes from, what it contributes to the curriculum and what its unique qualities are, and how excellence in students should be assessed. Part 1 describes and analyzes the evolutionary steps in the emergence of technology in the curriculum with a focus on the last 30 years. It traces the historical evolution of design and technology in the United Kingdom as a school subject, pointing out how it complements and differs from science and craft. Part 2 describes a national assessment that the author developed to find out what students learn from technology taught as design and summarizes the results. These findings are reported: girls appear to be better at identifying tasks, investigating, and appraising ideas, whereas boys seem to be better at generating and developing ideas; and Craft Design and Technology course students consistently outperformed the control group. Part 3 describes why technology education has been so successful. It points out some compelling reasons that have led head teachers, administrators, parents, politicians, and employers to value the contribution that it makes to children's development: the closeness between the process of design and technology and the process of thought; the centrality of communication; cooperative learning; and the direct link between technology in schools and subsequent industrial employment. Contains 35 references. (YLB)

Technology in the School Curriculum

Contractor Report

April 20, 1995

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Preface

In the United Kingdom, design and technology have been combined into a new school subject that is intended to prepare all young people better for the modern world. Students gain in-depth experience before the age of sixteen in actually designing and building practical technological systems that are sound and meet real human needs. This new subject has a larger place in the elementary and secondary school curriculum in the United Kingdom than do the various forms of technology education that are being tried out here in the United States. The author of this paper, prepared under contract to OTA for its study, "Testing and Assessment in Vocational Education (March 1994)," traces the historical evolution of design and technology in the U.K. as a school subject, pointing out how it complements and differs from science and craft. He also describes a national assessment that he developed to find out what students learn from technology education taught as design and summarizes the results. The assessment employed methods of performance assessment to describe student's capabilities in actually designing and carrying out solutions to technological problems. In the last chapter he articulates reasons why he believes that learning about technology as design may be especially valuable for students in these modern times.

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John Wirt
Project Director

GOLDSMITHS' COLLEGE
University of London

Technology in the School Curriculum

A report prepared for the Office of Technology Assessment
Congress of the United States of America

by

Professor Richard Kimbell
Technology Education Research Unit (TERU)
Goldsmiths' College; University of London

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Contents

Introduction

This report has been compiled at the request of the Congress of the United States - Office of Technology Assessment. It follows a seminar held in Washington in March 1993 to which I was invited to describe some of the issues and events that are developed more fully herein.

The report is presented in three parts which seek to answer a set of related questions in the context of the United Kingdom;

- Where did Technology Education come from?
- What does it contribute to the curriculum- what are its unique qualities?
- How are we to assess excellence in our students?

Technology i. emerged only recently in the British curriculum - though its antecedents are numerous and ancient. But it is only thirty years since the first steps were taken to establish technology in anything like its present form. In that short time it has moved from being a side-show intended only for the less able, to being at the heart of the new National Curriculum (NC) - a compulsory study for all children from 5 to 16 years of age. This is a massive achievement given the inertia surrounding the British curriculum.[1] It is quite remarkable that this new activity should have been so successful in elbowing its way in. There must be some compelling reasons underpinning its success.

In part one of this report I attempt to describe and analyse the evolutionary steps in the emergence of technology in the curriculum and I shall focus on the last thirty years. In part three I outline attempt to describe why it has been so successful; picking out some of the compelling reasons that have led head teachers, administrators, parents, politicians and employers to value the contribution that it makes to children's development. In part two of the report, I attempt to achieve a double purpose both of which revolve around the central question for any curricular activity - how do we know what effect we are having on pupils? This is the assessment domain. I have sought both to describe the Department of Education's major research exercise in the assessment of pupil performance in technology and to indicate how this research has extended our understanding of the nature of capability in technology.

1 Raymond Williams in his book "The Long Revolution" provides a detailed account of the emergence of the British Curriculum and concludes that it is "dominantly 19th century, with many 18th century features and a mediaeval core".

The Evolution of Technology and its Assessment

I have chosen to present this section of the report chronologically. The weakness of this mode of presentation is that the separate strands of the story are teased out across the whole time frame and thereby lose some of their internal coherence. The strength however, is that it has enabled me to link the major milestones in the development of technology education into a moderately coherent story.

1960s

Technology squeezed into the curriculum at the interface of science and technical or practical studies. It has inevitably therefore been shaped on the basis of the prevailing pedagogy in those two disciplines. Furthermore, given the diversity of curriculum practice in the 1960s it was equally inevitable that in its early stages, technology would not emerge as a single coherent entity but rather as a series of initiatives, each with a leaning towards one or other of the principal parents.

Crude characterisations of the two roots would show them to be dominated by a highly didactic methodology. In both cases pupils were seen to be empty vessels to be filled up with the desirable commodities on offer; respectively a large body of knowledge in the physical sciences and a large body of skills in wood and metal workshop practice. Typical activities in science would involve the dictation of "facts" about a phenomenon - or in better resourced schools the copying of notes from books - possibly followed by an "experiment". This experiment would be set up in such a way as to "prove" that the facts were correct, and indeed my own notebooks are full of experiments "To prove that...." We all knew that any divergence from the facts we were supposed to be proving was undesirable, to the extent that even when the readings from the experiment clearly failed to prove it, they would be interpreted so that a fit might be seen to be possible. Very much the same methodology informed practice in wood and metal workshops, only here the currency of exchange was not knowledge so much as skills. Teachers were highly skilled craftsmen who took us through a sequence of practical projects that progressively introduced us to - and helped us to become proficient in using - hand and machine tools.

The practice of pupil assessment in these settings was predictable. Where the emphasis of teaching is on the acquisition of knowledge - the focus of assessment was not surprisingly on the extent to which pupils have acquired it and could remember it. Most assessment time in science was therefore devoted to tests of knowledge recall, supplemented with limited practical testing of experimentation skills. In practical subjects the tradition was slightly different - for though the focus of teaching was largely on the acquisition of skills, this was not seen as the exclusive or even the dominant area for testing. The academic tradition of school- based examinations emphasised the predominance of written tests, and even practical study areas were not to be seen as exceptions. Written papers therefore abounded on the underpinning theory of eg. wood growth, timber jointing and steel manufacture. These recall assessments were then supplemented with practical tests that typically involved the making of a specified article to a set drawing in a set time (pencil box with sliding lid in 4 hours).

It is important to note here that there was no perceived relationship between these two roots of technology. What went on in science labs was science, and the space between them and the workshops was both real (the workshops were well away adjoining the playing fields) and symbolic of the intellectual gulf that divided them. The fact that they had a very common pedagogy was not sufficient to bridge the gulf.

Official Concern at an Unsatisfactory System

Two official reports on the education system in the late 1950s and early 1960s expressed considerable disquiet at the state of the education service. The reports were complementary;

- "15 - 18" The Crowther Report (DES 1959), focusing on the education of bright 17 and 18 yr old pupils; ie the potential university entrant.
- "Half our Future" The Newsom Report (DES 1963), focusing on the education of 13-16 yr olds of average and below average ability; ie the imminent school leaver.

Both of these reports were seminal in terms of Technology Education for they drew attention to the extent to which schools were failing youngsters of all abilities through the predominantly dry and lifeless approaches to teaching and learning. Why - asked Crowther - do so many bright youngsters..." lose their intellectual curiosity before they have exhausted their capacity to learn"? In the famous chapter 35, the report recommends an alternative road to learning based on teasing out understanding from direct experience. Why - asked Newsom - does the education of 15 yr olds who are about to leave school bear no relation to the lives they are about to lead as independent citizens?

Both reports made great play of the practical. Unusually however (for that time) sophisticated arguments were advanced underlying the virtues of practical work. Crowther, concerned with the essentially academic youngster in the 6th form argues...

> The boy with whom we are concerned is one who has pride in his skill of hand and a desire to use that skill to discover how things work, to make them work and to make them work better. The tradition to which he aspires to belong is the modern one of the mechanical man whose fingers are the questioning instruments of thought and exploration.
> (DES 1959)

Here we have the *practical* clearly espoused as a route to intellectual growth. And shortly afterward, Newsom chips in with a parallel vision on behalf of the lower ability youngsters who are about to leave school...

> Pupils should be helped and stimulated to enlarge their understanding and practise their skills, often using direct experience as a starting point.....Objects made in the workshops should work. Time spent in the workshops was justified only if it should lead to thought and expression: they are not to be regarded as a substitute for thought for the less intelligent.
> (DES 1963)

These two reports led - almost directly - to the establishment of two curriculum research and development projects sponsored in both cases by the new Schools' Council, set up in the mid 1960s specifically to encourage curriculum development[1] . The two projects were respectively;

- *Project Technology* - which drew heavily on the physical sciences and sought to "help all children get to grips with technology as a major influence in society and as a result to help them to lead effective and satisfying lives". Its methodology was broadly to..." encourage technological activities in schools and thereby develop a range of abilities and provide motives which are often overlooked by more traditional approaches". (Schools Council 1968)

- *Education through the use of materials (subsequently called the Design & Craft project)* - which sought to rehabilitate craft work by generating a designer/maker ethic. Whilst based dominantly in the workshop environment, the project sought to develop a problem solving rationale for the practical; needing in addition to practical skills..."a skill to identify

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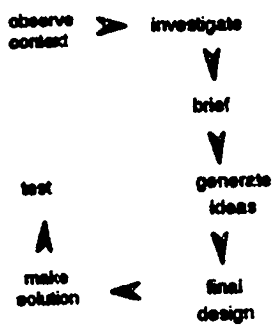
1 Interestingly, the second curriculum bulletin produced (in 1967) by the Schools Council was entitled "A School Approach To Technology". It is a good indicator of how high it was on the agenda.

and understand problems, to sift information and present reasoned argument". (Schools Council 1969)

Both projects contributed to a major development in assessment. Both were based - with different emphases - upon design & technological problem solving, and it was not surprising therefore that the problem solving ***process*** became the heart of assessment practice. To give a specific example, the Design & Craft project developed a 7 point design & make process which they translated into a 5 point assessment regime.



The process

	0 1 2 3 4 5
observe context & investigate	
brief	
generate ideas & develop design	
make solution	
test	
total	(out of 25)

The assessment model

For the first time, judgments were being made about pupil capability in the whole design and development process as well as in terms of the quality of the made outcome. This inevitably caused a major upheaval of practice, and amongst other things placed considerable emphasis on the pupils ability to develop a portfolio of drawings/sketches/models/prototypes that articulated the development phases of the idea. Recording the thought process became very important.

After the first ten years or so of the evolution of Project Technology, the focus had shifted from an unsatisfactory dispute about whether knowledge (from the science tradition) or skills (from the craft tradition) should be the dominant influence in fashioning technological curricula. The debate had moved to new and more interesting ground; essentially over the extent to which technology was to be defined as a *body of knowledge and skill* (from either of the two roots) or alternatively as an activity, the *process* of which is paramount.

1970s

Within the secondary schools (11-16 or 11-18), the influence of the 16+ examination cannot be overstated, and the two developments that are described below largely concern the development of two year (14 - 16) examination courses. The period leading up to these courses (11-14) was seen as providing a preparation or foundation for the examination courses and very few formal requirements were placed on it. While systematic development was focussed on the examination courses, the foundation courses were seen as an area in which teachers were able to make independent decisions.

Whilst schools and teachers pioneered individual - and often influential - pathways through these foundation courses, there is no doubt that throughout the 1970s, the two national research & development projects - leading to examination courses for 16 yr olds - carried the banner of curriculum development in technology. And they consolidated very different forms of technological activity in the curriculum.

Project Technology

Project Technology sought to develop three kinds of technological activity in schools:

- the whole technological *project* - from the recognition of a problem through to its resolution in a designed and made product.
- *structured courses* in particular bodies of technological knowledge, for example in electronics, pneumatics, structures, materials.
- *subject enrichment* in which for example a geography project might be enhanced through the development of an inclinometer or river flow meter.

The second of these approaches was particularly successful with teachers. The structured courses were increasingly developed into "modules" of study with serious theoretical input as well as practical exploration and they were marketed as "modular courses in technology". The modules were provided with detailed syllabuses, week by week programmes of study, prepared lists of equipment and resources, and prepared teacher hand-outs for pupils. For a teacher who was gingerly finding his (it was almost exclusively a male preserve) way into technology, it was a very supportive package. It also has to be said that these modular courses - drawing heavily as they did on applied science - were dominantly seen to be for the more able. Guidance to teachers on the pupils most suited to these technology modules was quite explicit.

> ...it is advisable that the following questions be answered in the affirmative;
> 1 Is the pupil in the top half of the ability range?
> 2 Is the pupil interested in any aspects of engineering?
> 3 Is the pupil practically inclined?
> 4 Is the pupil interested in science?
> 5 Is the pupil competent in mathematics?
> 6 Is the pupil interested in drawing?
> 7 Is the pupil interested in experimenting and innovating?
> (Schools Council 1973 quoted in Cross & McCormick 1989)

By the mid-late 1970s examination courses[2] in Modular Technology ran typically along the following lines:

- in year 1 of the course (15 yr olds) pupils study three modules from a list of eight, perhaps the most popular combination being electronics, materials & mechanisms.
- in year 2 of the course (16 yrs) pupils pursue a technological project from start to finish, making use of the specialist knowledge and skills they acquired in year 1.

Some wonderfully innovative work derived from such programmes, with one pupil designing an automatic dispensing system to feed his goldfish during a two week absence on holiday and another designing a pumping system that (using wave power) automatically baled out his dinghy moored in the harbour.

Such examination courses - which would largely be of the academic GCE variety - would then typically have the following assessment schedule:

- two written examination papers - carrying 30% of marks for each
  - one generic about the impact of technology in society

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[2] It is necessary to understand that in the 1970s there existed two separate examination systems at 16+. One system, the General Certificate of Education (GCE) was an academic examination designed for the top 40% of the population. It was seen as a precursor to Advanced level examinations at 18+ and thence for University entrance. The other system was the Certificate of Secondary Education (CSE) which was designed as a means to certificate the remainder of the population. The two systems reflected the division of schools - Grammar schools for those who passed the 11+ tests and Secondary schools for those who did not. In both examination systems the certificates applied to each subject studied, so an academic 16 yr old would expect to get nine good GCEs, and the average child in a Secondary school might achieve four CSEs.

- one specific dealing with the subject matter of the modules
- a major project
    - carrying 40% of marks
    - this would involve a full portfolio of design/development material as well as the final product and its evaluation in use.

The Design & Craft Project

The Design & Craft project developed along somewhat different lines - most obviously with less emphasis on applied science and rather more on practical workshop activity. The project saw itself redefining the context for designing and making in a way that took it beyond the school and out into the community. Groups of pupils were to be found redesigning footpaths and bridges in churchyards, or gutting the inside of the youth-club and refitting it to meet more carefully thought out needs.

The books and other resource materials emphasised the empowering nature of design in enabling us to intervene in and improve our environment. "You are a designer" is a source book typical of the project; very visual and diagrammatic and seeking to portray the ***process*** of designing in ways that appeal to pupils who would formerly have been restricted to the basic crafts of wood and metal work.

The assessment of the *thought processes* involved in designing was an issue that the project tackled head on and with great success and particularly in the context of the CSE examination that grew out of the project[3]. The whole examination revolved around the pupil's pursuit of a series of designing and making tasks, and in order to make them rigorous, the pupil's thought processes were tracked through the use of response booklets. They encouraged pupils to think through all the phases of the design task, keeping all the critical factors in mind and seeking out all the information that they might need to tackle it. For example in the context of a *playground redesign* the booklet would have required pupils to think at different points of the project about a wide range of matters:

- Who needs to be spoken to about the use of the playground?
- Who uses the playground and what facilities are required ?
- Are their any safety rules or laws that might be involved ?
- What do children like to have in playgrounds?
- What do supervisors need?
- What construction materials might be most appropriate?
- What budget applies to the project ?
- How might the phases of design and construction be planned ?

etc etc etc

The pursuit of answers to these and many other questions not only helped pupils to get to grips with the details of the task, it also provided written evidence (in the booklet) of the thought processes involved. The booklet used a double page of questions for each of the seven stages in the process (see p3), and along with the design folder, the booklet proved an invaluable assessment tool for teachers who needed to make judgments that went well beyond the quality of the end product - which might be a new seesaw or climbing frame.

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3 Whilst GCE examinations were typically traditional written examinations that were strictly controlled by University Examination Boards, the CSE examinations were very different and controlled by Regional Examination Boards. They encouraged the development of innovative assessment schemes - even involving 100% project assessment with no written papers. Schools - or in this case the Design & Craft project - could devise assessment arrangements for their course of study and submit it for approval by the regional board. The project developed a new examination called simply "Design Studies" which was approved by the NW regional examination group in 1972.

Comprehensive Schools Highlight the Examinations Problem

Throughout the decade there was a progressive reform of the education service that had the effect of transforming it from a selective system (Grammar and Secondary Schools) to a non-selective system in which the vast majority of pupils were educated in Comprehensive schools[4] taking all pupils from a community. This resulted in the two examination systems - GCE and CSE - becoming increasingly anachronistic and the pressure began to mount for a single system of examining at 16+.

The problem can be simply stated:

- the GCE system was traditional and academic and respected by the University establishment. It was not well loved by teachers - particularly those from former Secondary schools - who saw it as remote from teaching courses and as generally penalising pupils who did not have fluent literary skills.
- the CSE system was more closely tuned to the teaching in schools involving much more use of continuous assessment and a range of approaches in addition to traditional written examinations. CSE examinations were generally thought by teachers to provide more valid measures of pupil capability, but they were not generally acceptable (or at least not *as* acceptable) for university entrance.

Many pupils - particularly those in the middle ground - were given impossible choices between pursuing interesting, innovative courses that led to a qualification that had little currency in higher education, or alternatively slogging through much more traditional courses that resulted in a more 'valuable' qualification. By the late 1970s the pressure was building up to reform the examinations and provide a common system of examining at 16+. As we shall see, this pressure eventually resulted in a single examination system being introduced in 1986.

Assessment of Performance Unit

The 1970's were years of considerable development for Technology in schools, but there were also the first stirrings of another set of innovations - inspired by an increasing awareness of the need for accountability in education. The Assessment of Performance Unit (APU) was set up in the mid 1970's to monitor the education system. The basis of its operation was to develop tests for pupils at a range of ages (typically 8,11,13 and 15) and to administer these tests to a sample of pupils. Light sampling systems were developed involving 2% of the population in tests that would typically be 30-50 minutes long - with very small sub-samples engaged in longer practical testing. The idea underpinning APU was that the first round of tests would create benchmarks of performance which could then be checked on a 5 year rotation of testing that would tell us whether the system was improving or not and in what areas. The first round of APU testing in 1977-8 involved Language (English) and Mathematics, followed shortly afterwards by Science which came on stream in 1980. The Design & Technology APU project did not get into the frame until 1985, and the details of its approach will be examined in part two of this report.

Initial teacher reaction to APU was hostile because it was seen as a foot in the door for external accountability and appraisal. Progressively however it became seen as a real force for good - and for two reasons.

First, the fears about using it as a check on teacher performance were allayed when it became policy that all testing should be confidential; schools and pupils would be selected at random and not identified. They would represent the system without being individually accountable, and data from the testing informed the system as a whole. Second, it became ever more apparent that some very imaginative test development was issuing from the APU. The development of the

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4 There is some scepticism about how real this transformation was - as most Comprehensives were formed by the merger of a Grammar with a Secondary school in the same town and the internal selection systems often retained many features of the former arrangements. Nonetheless, 11+ testing largely disappeared.

assessment frameworks themselves were interesting and broke new ground, and when these led on to some quite new and (in teachers eyes) very valid approach to monitoring performance, the initial defensiveness of teachers changed into an open welcome. Despite the workload involved, when the computer selected a school for APU testing, the common reaction in that school was very positive. It was seen as providing (at someone else's expense) very good in-service training in assessment for the staff in the school.

The Design & Technology APU project, when it hit the schools between 1986-9, was seen to fit the innovating style of APU and was very warmly received.

1980s

If the 1970s was a period of development in Technology, the first half of the 1980s was one of consolidation. The driving force underpinning this consolidation was not restricted to technology, but involved a wider policy that might be seen as the first step towards the National Curriculum. It took the form of a wide ranging review of existing courses leading to a rationalisation of the examination syllabuses that were on offer at 16+. Why were there so many? Why did so many of them overlap with each other? Why was there so much duplication? The debate was as applicable in technology as it was in mathematics or any other subject. There were literally hundreds of different examination courses in design & technology, and in technology. They were all somewhat different from each other, and had grown (largely) from the opportunities that had been provided in the 1970s to develop customised CSE examinations for particular client groups and in response to individual curricula. Surely they could be rationalised somewhat?

Rationalising Existing Courses

The first stage of this rationalisation was to invite the Great and the Good in each subject discipline (in this case technology) to come together and write a set of ***National Criteria*** that would be universally applicable in any technology examination course. There was much blood on the walls in these meetings as well rehearsed and deeply entrenched positions were debated and challenged. And this was the debate that gave birth in 1985 to a uniquely British phenomenon - Craft Design and Technology (CDT). It sought to reconcile craft practice with design innovation and technological rigour and in very large measure it succeeded. The CDT National Criteria were universally adopted by the new Secondary Examinations Council,[5] and all examinations in the technological area had to meet these criteria.

Broadly, the CDT National Criteria allowed for courses of three kinds in the technological arena:

- *CDT: Design & Realisation* - focused on three dimensional product design and making
- *CDT: Technology* - focused on the design and manufacture of technological systems and products
- *CDT Design & Communication* - focused on the communication of ideas in designing and making. (Secondary Examinations Council 1985)

A Common System of Examining at 16+

This National Criteria exercise paved the way for the second consolidating step - the development of a common examination system at 16+, the *General Certificate of Secondary Education* (GCSE) which was launched in 1985 as the twin systems of GCE and CSE largely disappeared [6].

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5 The Secondary Examinations Council was set up in 1982 by Parliament to oversee and take responsibility for all examination courses in schools.

6 They were not actually banned, and GCE courses in particular continued to be used in some settings, but their currency was severely undermined and they have largely disappeared.

Apart from the revolutionary nature of a single examination for all - regardless of ability - there were other major innovations in this new examination, notably that it should identify ....“what pupils know, understand and can do”. In other words it was to be criterion referenced. We were going to lay out in advance what criteria of excellence would apply, and then measure the extent to which they were met by individual students. This stood in sharp contrast to the vast majority of former practice that was largely norm referenced and guided only loosely by mark schemes. Within the GCSE development we therefore subsumed a “Grade Related Criteria” exercise that sought to identify what qualities were involved at different grades.

Perhaps the most significant challenge in the development of GCSE lay within the problem of **differentiation**. How is it possible to have a single examination that can usefully be used to measure capability from the very slowest pupils to the very quickest and ablest ? The questions that one might want to ask this latter group may not even be intelligible questions for the former group. Does one - for example - create an incline of difficulty through the paper, such that the brighter you are the further you get ? One is juggling here with the effective use of time and with pupil motivation, as well as with the content of the subject and principles of education.

> We cannot believe that it can in any way be educationally desirable that a pupil of average ability should ...be required to attempt an examination paper on which he is able to obtain only about one third of the possible marks. Such a requirement, far from developing confidence, can only lead to feelings of inadequacy and failure.
> (SEC 1986)

Of all the possible ways forward in this complex area, the following approaches became commonplace in the first rounds of GCSE examinations in 1986, 87 and 88. In the case of written papers, use was commonly made of ‘stepped questions’. Assuming that a question paper has 10 questions, then each is divided into five subsections which are themselves on an incline of difficulty, typically starting with very concrete demands and becoming increasingly conceptual/theoretical. Whilst the best pupils do all the paper, those of average ability might only do parts a and b (and possibly c) of each question. In relation to project work it was widely held that differentiation could properly arise through the *response* of pupils to standard tasks. An able pupil would do something more interesting/innovative/challenging than an average pupil - even though the set task was the same. This became known as ‘differentiation by outcome’.

GCSE examination courses developed along these lines through the rest of the 1980s attracting widespread support.

- *Teachers* liked them because of their broadly educational format,
- *Employers* liked them for two reasons - because they had only to deal with a single system of certification and because the criteria of excellence were explicit,
- And generally *pupils* liked them as the confusion of the former twin systems was removed, and because GCSE examinations inherited many of the more pupil-friendly strategies of the CSE system.

There were doubters of course, and prominent amongst these were the defenders of a more traditional academic curriculum (typically in the remnants of the old Grammar schools) who felt that the rigour of former GCE courses had been diluted and that examination standards were accordingly on the slide.[7].

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[7] This debate still rumbles on with the Education Minister announcing early this year another review of GCSE examination standards.

Nevertheless, by the end of the decade, there were many different CDT courses running[8], and generally in ways that were thought to be highly effective. They all held to the CDT National Criteria and were all - of necessity - scrutinised and approved by SEAC[9].

The Assessment of Performance Unit

The APU project in Design & Technology was launched in 1985. A sequence of APU science surveys between 1980 and 1984 had contributed to interest in technology, partly because of the practical investigations that were part of the science APU framework. Furthermore CDT in schools was attracting widespread interest amongst educationalists at all levels as well as with industrialists and politicians and eventually a series of manoeuvres led to the acceptance of design & technology within the APU monitoring schedule.

The brief was to identify the technological capability of the 15 yr old cohort in schools in England, Wales and Northern Ireland. At this time, CDT was seen as the core of technology in schools and was being studied by approx 35% of pupils[10]. But this presented interesting problems for the project, for all former APU surveys had been in areas of compulsory study - like English and Mathematics. We[11] were therefore in a position of having to develop monitoring (testing) approaches that provided open access for all pupils regardless of their technology curriculum but that provided good data on those with high levels of capability as well as on those that had very limited experience and capability. We evolved an assessment framework, developed a series of test instruments, ran a pilot study in 1987-8, redesigned the instruments and ran the main survey in 1988-9 and subsequently analysed the mass of resulting data. The final report on the whole project (Kimbell et al 1991) was published in 1991 - along with several supporting pamphlets for teachers. These were fed into schools on a regular basis between 1990 and 1992.

The technical details of the project need not concern us here. The tests themselves - how they were designed and what they can [and can't] tell us about pupil capability - will be the subject of the 2nd part of this report. With regard to the evolution of technology in the curriculum however it is worth noting here that the project provided three significant steps forward.

First it proved that short tests (90 minutes) could be designed that would provide good data on pupil *performance* in this area. This is very different from the GCSE kind of testing which involved short *theory* tests and extended project assessments over anything up to 12 months. For APU we developed short tests, but they were not 'theory' or knowledge tests. They were genuine capability performance tests - but in a specific context and time frame. Moreover we proved that it is possible to assess very reliably the pupil responses to these tasks.

Second we discovered that the core capability in technology cannot be defined simply in terms of a body of theoretical knowledge and an ability to use materials and tools. The data is unequivocal and shows that it is - critically - the *relationships* between the two that marks out the excellent technologist. Understanding is no use if it cannot be put to use, and practical skills are only as useful as the mind that applies them in fruitful ways. The performance data show quite clearly that being able to operate on both levels simultaneously is the key to excellence. The brightest pupils (on abstract physical science understanding) do not make the best technologists - and neither do the skilled crafts persons. Technology requires a new breed of person who can operate freely at the interface. We were able to identify such people despite the fact that for the vast majority of pupils, and for the vast majority of the time, schooling creates an artificial divide between the

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8 The old CSE and GCE examining bodies were reconstructed into regional clusters and became Examination Groups - eg London & East Anglia Examination Group (LEAG) and Northern Examining Association (NEA). Each of the groups drew up their own syllabuses for courses in CDT - but all had to meet the National Criteria.

9 In 1988, the Secondary Examinations Council was redesignated the School Examinations and Assessment Council (SEAC), extending its remit to assessment and to Primary schools.

10 Approx 60% of boys and 10% of girls

11 The project was based at Goldsmiths' College, University of London, under my direction.

cerebral and the practical. We coined the phrase "thought in action" to describe this quality of capability that turned out to be so influential.

Third, the APU project was sandwiched between the development of the GCSE examination system (which was well underway by the time of the APU survey in 1988/9) and the embryonic strugglings of the National Curriculum, which in terms of technology was formed by a 1989 Order of Parliament (DES 1989). Our major contribution to these developments lay in the fact that, having clarified that what we were assessing was a new kind of capability [a hybrid of the academic and the practical] we also showed that it was reliably assessable. These features were important to different constituencies, but together made the further development of design & technology politically very attractive to those seeking to reform education.

The National Curriculum

It seems incredible even as I write this, but just as the GCSE innovation was beginning to get organised in 1986-7, and as the APU project was beginning to develop new ways of looking at capability, yet another far more fundamental shake-up of the curriculum was being launched. It is impossible to do justice, in a few paragraphs, to the policy developments that led to the establishment of the National Curriculum, so I shall only touch on these lightly and will concentrate on the consequences for Technology.

Broadly, the NC is seen as having ten subjects; English, Mathematics and Science as the core subjects and seven others (including Technology) in the foundation . Each subject is defined in terms of *Programmes of Study* (PoS) (that which will be taught) and *Attainment Targets* (ATs) (that which will be achieved and tested)[12] . These were developed by subject working groups which included the Great and the Good in the discipline as well as industrialists and other interest groups. The ATs and PoS are arranged across ten levels that are seen to cover the whole of a pupil's school experience from 5-16 years (level 2 is average performance for 7 yr olds, level 4 for 10/11 yr olds and level 6 for 14/15 yr olds). Within the ATs, there are numerous *Statements of Attainment* (SoA) that are essentially the assessment criteria that apply at each level and within each AT (see figure next page)34-.

In Technology [13] the definition of capability is enshrined in the ATs and can clearly be seen to be the offspring of all the earlier definitions - as far back as the 1960s (see page 3). It '. dominantly process driven, the four ATs summarising the activity of designing and making from initial understanding of the need, through design and development, manufacture and evaluation[14] . The PoS contain, at each level , the body of knowledge and skills that is to be taught to pupils to support this process.

Whilst the NC definition of capability is conforming to the traditions that have underpinned the emergence of design & technology, the assessment regime is breaking quite new ground. The SoA are detailed criterion statements that are to be achieved by pupils before they can be awarded a level. To that extent therefore they can be seen to derive from the GCSE criterion statements. But their mode of operation is quite new.

The GCSE system used groups of criteria to help teachers form a *judgment* of quality. For example if a teacher was trying to decide how good a pupil's evaluation of her work was, they were supported in the decision by the use of the following criteria;

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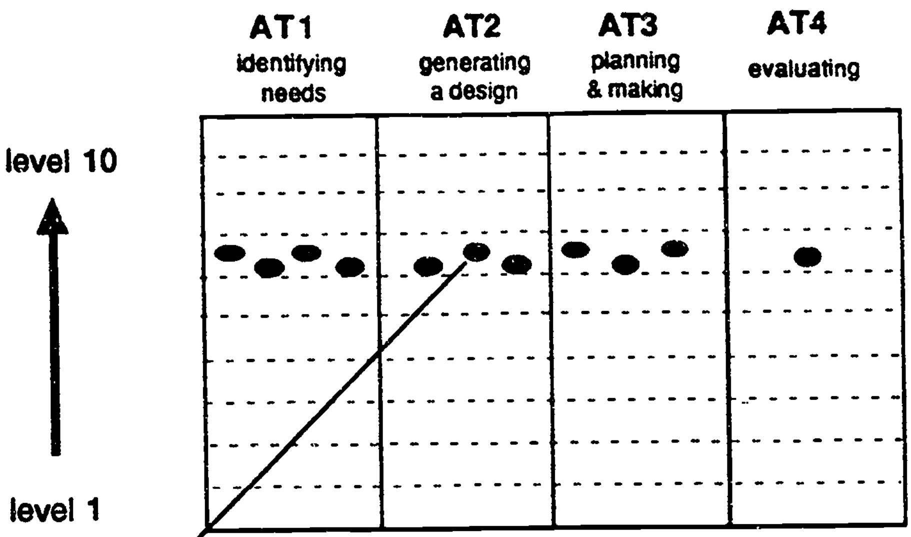
12 The founding document for this structure is the TGAT report - the Task Group on Assessment and Testing. It laid out the structure for presenting NC subjects and the mechanisms for testing.
13 The National Curriculum subject is called "Technology". It is contributed to by a range of former 'subjects', prominent amongst them being CDT. It also includes elements of Home Economics, Business Studies, Information Technology and Art & Design.
14 This NC definition is currently under review again after the first two years of operation. Some changes are to be expected - but this active description of capability will certainly be retained.



At level 7 there are 11 Statements of Attainment (SoAs) that need to be achieved across the Attainment Targets (ATs)

Across all levels there are 119 SoAs

"review the detail of their design, and suggest alternative ways of achieving what is needed" (DES 1989)

They make their decision, and (say) 3 marks might be awarded. These were then added to all the other marks (for investigating, generating ideas, planning, making etc) and thus the whole project achieved a mark out of 100.

Within NC assessment, this arrangement has been entirely changed and the 119 SoA are seen as individual criteria to be scored - yes or no. To achieve level 4 you need to register a 'yes' for each of the level 4 SoA - and there are 15 of them.

The candidate's evaluation;

0 - has not been attempted;
1 - is irrelevant;
2 - is relevant but superficial;
3 - represents an honest attempt to appraise his or her work but lacks objectivity and is either incomplete or not altogether relevant
4 - is complete and largely relevant but lacking in objectivity
5 - is thorough, objective, relevant and concise: it would provide a useful source of reference for later material

GSCE evaluation criteria

This has resulted in teachers - for the first time in my experience - carrying around large tick-sheets on which to mark off individual SoA in respect of each of their pupils. It is a very cumbersome system and in a sense it is anti-judgmental. It is not possible (or at least not supposed to be possible) to sit back and take a broad view of the pupil's capability. The final overall measure of capability is supposed to emerge from an aggregation of all of the small SoA judgments. But this is a very dangerous policy in Technology - as indeed it is elsewhere - as so many qualities of capability are not independent but interact with each other. It's a bit like scoring a child who is learning to ride a bike and using separate marks for steering, balancing and pedalling. We can all identify that moment when the child's riding takes a leap forward and s/he stops falling off the bike, but this critical moment does not derive from an advance in any one of the three bits of capability, but rather from grasping their interdependence.

Teachers are giving loud (and increasingly angry) voice to the fact that they are being submerged under a deluge of tick boxes and form filling, much of which they see to be of dubious value. And moreover the NC assessment arrangements are widely seen as having the effect of reducing the possibility of professional judgment that teachers are used to exercising in assessing the capability of their charges. This impression is not helped by the fact that the final assessment for a pupil emerges from the application of complex formulae to the pattern of yes's and no's that the child achieves in the SoA.

Clearly the NC assessment regime is founded on a set of principles to do with strict criterion referencing and a 'mastery-testing' model. But the capability it is seeking to assess is exactly the same capability that was formerly assessed by other means, and the experience of the last two years suggests that a cherry-picking approach to assessment is not easy to operate and not very helpful (either for teachers or for pupils) in developing an understanding of the qualities required.

1990s

Technology is now in danger of falling victim to the coincidence of history. Technology has emerged over the last 30 years into a powerful educational force that has been widely welcomed by teachers, pupils, parents and employers. So much so that it has become a mandated part of the National Curriculum - a compulsory study for all pupils between the ages of 5 and 16 years. This is an enormous achievement, indeed it is a staggering achievement when one reflects upon the deeply traditional structure of the vast majority of the British curriculum. Raymond Williams in his book "The Long Revolution" recounts the development of the curriculum and concludes that it is dominantly 19th C, with significant features from the 18th C, and with a mediaeval core. Given the sheer tenacity and longevity of so much of the British curriculum, it is indeed remarkable that a new discipline should have elbowed its way in over a period as brief as thirty years.

However, its adoption into the National Curriculum made technology a requirement for all pupils within all schools. And by a sheer fluke of history, within the same legislation, the assessment arrangements for *everything* in schools were utterly transformed. The transformation has not been smooth, and technology has become synonymous with the problems of NC assessment.

The original description of technology by the National Curriculum Working Group represented a natural evolutionary progression from the thirty years of development that led up to it. It was process-based, task centred, and concerned with building technological capability (see also part three of this report). But it has proved to be a very difficult beast to assess using the NC assessment (tick-box) regime. Whilst all teachers find it difficult to fit what they would normally do to this new arrangement, technology teachers in particular are in difficulties.

Subjects that can be defined in terms of strict bodies of knowledge and sets of skills might just be amenable to such an approach, but technology represents the antithesis of this. There is more than a little potential truth in the quietly spoken despair of a senior civil servant when he confided the view that "technology might be the rock on which the (NC) assessment arrangements founder". Whilst technology might be the leading contender in this, the current dispute over the testing of English demonstrates that it is, in reality, a widespread issue of concern.

In my experience, when a ship is about to hit a rock, it is profitable first of all to question the direction of the ship. But until very recently the preferred policy has been to move the rock and the immediate target for action has been the definition of technology itself. The 1989 NC definition has been judged to be flawed and a Review Group has been charged with the task of making it more "manageable". And there are perceived to be two sides to this question; (i) reducing the procedural complexity (reducing the ATs, reducing the number of SoA , and (ii) reducing their 'sophistication') and spelling out the content (the body of knowledge and skills). Predictably - given a brief of this kind - the preliminary findings of the review suggest that we might be heading backwards. Whilst all practitioners recognise the role and importance of the knowledge and skill that underpins technology, it is also widely understood (again by the practitioners) that these bodies of knowledge and skill do not - of themselves - provide an adequate definition of what technology is and how it contributes to pupils education. It is for these reasons that the original Working Group drafted statements of the kind that they did ....

> Review the ways in which their design has developed during the activity, justifying their decisions and appraising outcomes in terms of original intentions.
> (DES 1989) (NB. this is intended to be suitable for 12 yr olds)

Of course it is difficult to judge such statements as 'yes' or 'no' as is required by NC assessment, though teachers are quite familiar with handling judgments of this kind with the sliding scale GCSE system. The Technology Review Group felt that statements like the one above are "too complex" to be useful. The crude assessment mechanism was creating the need for simplistic assessment statements.

So technology stands at the cross-roads. After thirty years of development we are again plunged into a fierce debate about the rationale and educational significance of technology.
We have evolved a sophisticated, challenging and forward looking model of capability in technology. Yet at the same time we are seeking to assess this capability through inappropriately mechanistic means. The two things would not fit together and something had to give.

In May/June this year (1993) an astonishing event took place. The whole panoply of NC testing crumbled in the face of an unprecedented piece of direct action by teachers. In the face of instructions from the Minister of Education - and at one time the threat of legal action - almost every school in the country simply refused to run the NC tests. The issue was not merely about technology, though English and Technology were the most frequently cited subjects of aggravation. The results of this remarkable event have been numerous but for the purposes of this story the most significant has been a rolling back of the unhelpfully prescriptive assessment arrangements.

The Dearing review[15] has recommended in its Interim Report a significant simplification of the statutory requirements of the NC and a major slimming down of the testing regime. In the process it appears that the strict criterion referencing procedures are to be mediated by broader approaches with more scope for teacher judgment. In short, we appear to be moving back to a more flexible pattern of assessment and this bodes well for Technology. However, the review of the definition of Technology is still 'live' and its conclusions will not be finalised until the Dearing review has published its final report later this year.

It is all still to play for, and the balance of the argument appears to be moving in a direction which would allow technology to continue to flourish - with all the educational benefits that I have attempted to illustrate in part three of this report.

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15 Sir Ron Dearing - a professionally respected person - has been asked by the Minister of Education to head a review team for the whole of the NC arrangements, including the assessment arrangements.

The Assessment of Performance Unit (APU)

This part of the report is itself written in three sub-sections.

- In the first, I shall outline some of the ***principal issues*** that emerged in the development of the assessment framework and the tests.

- In the second, I shall outline some of the ***principal findings*** (data) in relation to pupil performance.

- In the third I shall explore the ***longer term impact of the project*** on the development of policy and practice for design & technology in the curriculum - and especially the UK National Curriculum.

The background to the establishment and the principles of operation of the APU are outlined in part 1. Within this section, I shall examine the work of the Design & Technology APU project based, under my direction, at Goldsmiths' College London between 1985 and 1991. We were charged with monitoring the technological capability of the 15 yr old cohort in England Wales and Northern Ireland. The 'light sampling' principle of APU monitoring - in which a 2% sample of pupils is used to represent the nation's pupils - was applied as with all other APU surveys, and moreover we were required to do the bulk of the testing by post using short, standardised (90 min paper and pencil test) techniques.

It is easy to see why we were somewhat dubious about the brief. Pupil capability in technology generally unfolds over an extended period of time and - at least in part - through the interaction with materials and tools. We were not convinced that this capability could effectively be monitored in any realistic way using short pencil/paper tests. We therefore developed a three pronged assessment framework that linked short pencil / paper tests with longer, more practical and more 'real' activities and we designed a survey that allowed us to cross relate performance between them. In the end, for reasons that will become apparent, the short tests provided some remarkable insights both into the capability of pupils and into the nature of the activity.

Issues Emerging From the APU Test Instruments

We developed a series of approaches to testing that can be categorised into three broad classes.

90 minute pencil/paper tests, in which pupils completed structured tasks, working with restricted resources in a specially designed pupil response booklet. Because of the degree of external control that we exerted on these tests, and the fact that large numbers of pupils were involved in them, this element of the survey provides the most statistically reliable data. However, because of the short time allowed, each task only examines certain aspects of capability. (see Kimbell et al 1991 section 7)

Modelling tests, in which a selection of the 90 minute test tasks were supplemented with extra time (half a day), a range of soft and rigid modelling materials and the opportunity for pupils to collaborate in teams. These tests had strong elements of control within them, and involved pupil collaboration and discussion. The sample size for these tests was large enough to provide statistically reliable data, but the tests were run by trained administrators who could provide additional illuminative assessments. These tests were therefore seen as a bridge between the 90 minute tests and the third branch of the survey. (see Kimbell et al 1991 section 8)

Extended Project Profiling, in which field workers monitored pupil performance on real projects underway in schools over an extended period, in some cases as long as 9 months. The field workers conducted regular, individual interviews with pupils, collecting detailed information throughout the project and building up case records of individual pupil performance. In this strategy, the emphasis was on collecting illuminative rather than statistically reliable data. Because the *whole project* was scrutinised, all aspect of performance could be monitored and assessed. (see Kimbell et al 1991 section 6)

The data from each of these approaches was triangulated by having the modelling test sample and the project profiling sample ***also*** doing selected short tests.

Despite the obvious differences in these approaches to testing, they were built around a common concern for the integrity for the designing, making, evaluating activity. This is most clearly evidenced in the project profiling work, but was equally a concern in the 90 minute and the modelling tests. It is obvious that a real design task cannot be taken from inception to completion on paper in 90 minutes, and it was these tests that provided us with the greatest challenge. Nevertheless before explaining how we coped with the challenge - it is important to recognise that because of our view of the nature of technology in schools we were committed to ***performance*** testing - not knowledge and skill testing. And performance testing in Technology means finding ways of measuring how well pupils are able to originate ideas, organise their time and resources, conceive of alternative possibilities, model solutions and evaluate them against user needs.

Not surprisingly, the first and major challenge was to get pupils to the point where they could recognise a short test (in a test booklet) as being a design & technology activity. They knew they were being tested, and we had to find ways to get them out of the "right answer" mode of response that they were so accustomed to in testing. These problems we classed together as being concerned with the need to *get the activity running* properly in the first place. Subsequently - assuming one has generated a good activity and the pupils have produced some appropriate responses to the tasks - there are the further consequences concerned with *making assessments* of their performance. The first group of concerns has natural priority and will be dealt with first.

Getting activities running

The context of tasks. Real tasks do not exist in vacuo. They exist in real houses or gardens or shops of car parks or hospitals, and the *setting* of the task is a major determinant of the *meaning* of that task. If you were invited to "design a door handle" it would have very little meaning until you could see the context for which it is intended. It might be for a child's play-house, or for an industrial kitchen, or a heavy goods vehicle. In each case the issues that the designer needs to consider are to a large degree defined by the *context*. Equally, the success of the outcome can only be determined by examining its operation in the same context.

We used a series of 8 minute videos to capture the range of contexts within which our tasks were embedded:

a pre-school play-group,
a post office,
an elderly lady's kitchen,
a back yard;
an industrial production line,
and a design studio.

These settings not only created meaning for the task - they also provided important cues to help the pupil to get started on the activity. If asked to design a *leaflet storage and dispensing system* for the post office, the video of the post office not only fleshed out what that task meant, it also provided some potential lines of design development to get the pupils up and running on the task. Who are the users? what do they need? how do they typically get the leaflets at the moment? what problems exist? These practical issues become jumping off point that give access to the task.

The first critical message from our testing is that tasks must be contextualised; firstly because it provides meaning and secondly because it provides starting points for action. As a research exercise, we ran the same tests with and without the initiating video and the results were highly significant and demonstrated the empowering nature of the contextualising.

The hierarchy of tasks. Having established a context however, the nature of *task setting* has a serious impact upon the do-ability of the task. And the most significant aspect of this 'task effect' is procedural rather than conceptual. It matters relatively little whether the task is do with developing a post office leaflet storage system - or a childs toy. The different content is barely significant in determining how well pupils are able to perform. But is matters a great deal whether the task is set *loosely* or *tightly*. As explained above, we used contextualising videos to set the scene for the tasks, and thereafter we set the tasks at a range of levels of specificity.

1. In some tasks we provided little more than a generalised suggestion that the context was full of potential problems that could usefully be pursued by a designer; for example "think about issues of *protection* in this context..." We then left the pupils to identify for themselves the specifics of the tasks they might pursue.

2. In other tests we provided a more comprehensive framework for the task by adding more precise demands to it ; for example ."...think about *the protection of personal possessions from theft."* Naturally, pupils were getting a better 'steer' from us in these tests - but still had the opportunity to derive quite disparate tasks within the context.

3. In the most tightly specified tasks we went yet further and added quite specific design requirements to their task; for example "....design a travellers body purse..". Here was a quite specific starting point that provided little room either for negotiation or for confusion.

As can easily be seen, these three tasks are hierarchically related.

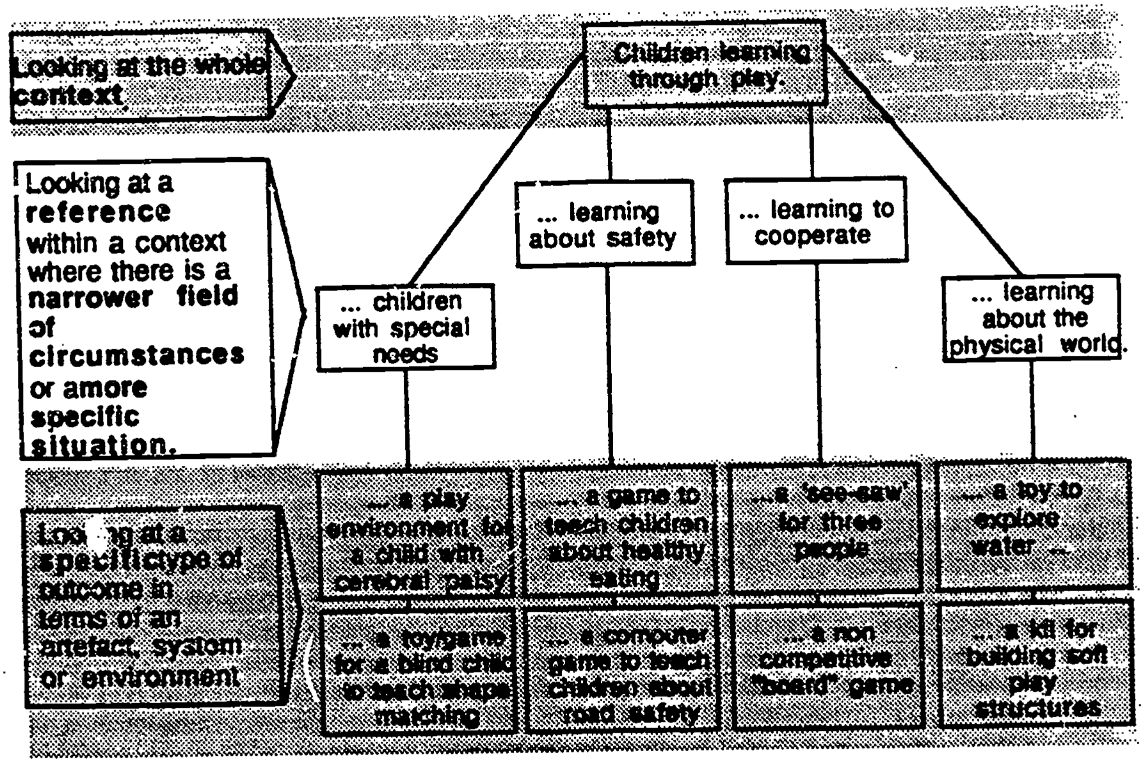
Contextual task -> Framed task - > Specific task

And the same structure can be applied to any context you care to mention.

It is easy to understand the differences of demand that exist within these layers of task setting. The contextual level provides plenty of opportunity for pupils to 'take ownership' of the task, because they are - in a very real sense - deciding for themselves what the task will be. But there is very little support in it; it is not clear exactly what pupils should get on and do, and it might be easy to spend a long time unproductively trying to find a real task to get into. At the other extreme is the reverse problem. It is quite obvious what the task is - and hence quite apparent how one might immediately proceed, but it is much more difficult for pupils to generate any personal ownership of the task. What do we do with the pupil whose reaction is ".....I'm not interested in, I don't want and I don't need a body purse.."? Would the test then be a fair measure of their capability?

The big question of course is how these different layers of task setting affect pupils performance on the tests. Before answering it however, the issue has to be taken a stage further, for the question of openness or specificness does not just relate to task setting - it also relates to the whole procedure for pursuing the activity.

Structuring the activity. Assuming that 90 minutes is available for the activity, it can be managed in any number of ways, and our tests reflected this diversity. In some we left the structure very open - with large blocks of time available to the pupils and only limited interventions by the administrator to steer the activity. In these tests, average sub-activity times (between interventions) would be approx 20 mins. Other tests we structured much more heavily - with more interventions and instructions by the administrator. Average sub-activity time here might be as short as 10 minutes.



A hierarchy of tasks

Again the strengths and weaknesses are obvious in retrospect. In tightly structured activities there is plenty of support and few pupils lost their way in the activity. But by the same token there was little opportunity for pupils just to get on with it - as we kept stopping them. In the more open structure it is much easier to waste time - or lose one's way completely - but those that were on task could get on without interruption.

These two design features of the tests - closed or open tasks and tight or loose structures - had a marked impact on the performance of different sub-groups of pupils. Put very simply, on average -

- girls perform better than boys on open tasks
- boys perform better than girls on closed tasks
- pupils of lower general ability perform better on more tightly structured activities
- pupils of higher general ability perform better on more loosely structured activities.

A further clear finding was that..

- the greater the experience of Design & Technology that pupils had been exposed to in their curriculum, the less marked these tendencies became.

It is also interesting to note that the most successful sub-group of pupils in our tests was high ability girls who had engaged in a significant amount of Design & Technology in their curriculum.

The iteration of action and reflection. A final major issue in regard to test structuring concerns the balance that is struck between active design activity (drawing, modelling, making etc) and reflective appraisal of where they were going (identifying issues for judgment, identifying strengths and weaknesses in the work etc). *It became obvious from a very early stage that action and reflection need to be kept in balance in any technological activity.* Technology is about the active pursuit of real problems, but it must be focussed and directed by continuous awareness of the needs being met, the priorities of the users, and the strengths and weaknesses of the work so far. And in a technological task (as probably in any task) the relationship between action and reflection is iterative. Action forces issues into the daylight, and those issues then raise further directions and possibilities for action.

To get a measure of the significance of this phenomenon, consider then the difference between these two test structures for the 'evaluation' test that involved the critical evaluation of a pair of supposedly similar products:

Test structure (a)

- video contextualising
- identification of criteria of judgment for the product
- examination of the product
- identification of strengths and weaknesses of the product
- redesign to improve the product

Test structure (b)

- video contextualising
- examination of the product
- design development of a new product to be better than it
- identification of criteria of judgment for original product.
- identification of strengths and weaknesses of original product

Both structures have the same five elements, but they arise in a different order. And the major difference is in the position of the **active** designing (stage 5 or stage 3), as opposed to the **reflective** identification and consideration of criteria, but this has enormous consequences for pupil performance, especially in terms of the richness of the criteria subsequently identified as important. If you are able to think about these criteria having already tussled with the design challenge, then you are more aware of what is important and what is not important. The performance data are quite clear on this point, and the interdependence of thinking and doing in technology enables us to understand clearly why it is so. (see Kimbell et al 1991 section 3 and Kimbell 1991 (b) p 149)

Over a period of 18 months - during which time these various test effects became apparent to us - it became progressively more possible to develop a set of tests that allowed pupils to demonstrate creative technological capability in a relatively short time and in response to a standard set of tasks. Exactly these same issues applied to the design of the modelling tests - which were longer, involved the use of real materials, and allowed for elements of group collaboration. There were however two additional strategies that proved to be particularly important to the success of these modelling tests.

Pupil discussion in the modelling tests. Perhaps the most startling outcome from the development of the modelling tests was our realisation of the role and importance of group discussion. From the earliest trials we were aware of the impact that it had on the crystallisation of design ideas and in the final version we deliberately set a 20 minute discussion into the middle of the design & development phase of the tests. In turn, each of six pupils was asked to say (in two minutes) what they had done, why, and what they proposed to do next. It was then open for peer comment around the table - with the chairperson (the administrator) being strictly constrained to neutral questions as prompts if necessary. It seldom was necessary - and in the vast majority of cases the interaction proved immensely significant in helping pupils forward in their designing.

One of our test administrators commented:

> This was a strategy that I had previously not put any emphasis on in my own teaching and I found it by far the most useful device for helping pupils extend their ideas. The pupils' response to each others criticism was a major force in shaping the success or failure of the artefact in their own eyes. Pupils saw this as a very rewarding activity and would frequently modify the direction of their own thinking as a result. (Kimbell et al 1991 p 123)

This was a common reaction among the administrators. Even though we had selected the administrators on the basis that they must be very good practitioners of technology teaching, none of them had previously made significant use of this collaborative technique, and this alone speaks volumes of the perception of the teaching and learning regime. It is so often seen to be an individual, personal activity. One of the clearest message from our modelling tests is that opening it up to group discussion in a supportive/critical framework, is highly effective improvement strategy.

The use of materials and resources. The other major feature of the modelling tests concerned the use of resources ie. materials and tools, and the problem of how to do it. If you set a task and then say "these are to resources you have to work with" then pupils spend ages exploring the resources and often get led by them into solutions. We wanted pupils to lead with their *own* ideas and use resources in support of those ideas, and this required a more critical access to resources. We (eventually) resolved this problem by setting up a shop - for which the test administrator was the shopkeeper - and to which pupils could come and ask for resources. "I want something that will do ...." "have you got a cutter that can ...." "I want a piece of ...." "have you got anything like ...." The pupils ***ideas*** were leading their access into resources.

This again proved an important development, preventing dilettante fiddling with things that just happened to be there, and encouraging a more critical mode of access.

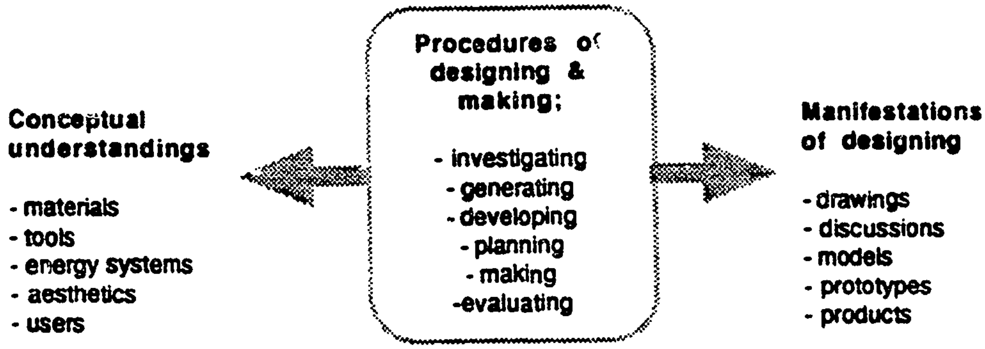
Taken together with several other less significant factors, our progressive awareness of these issues of test construction allowed us to design short term technological activities to which pupils were able to respond with flair and conviction. The archive of pupil responses is rich with diverse and creative work. We were confident that this part of our task was satisfactorily in place - but it was only half of our task - for we had then to work out ways of making reliable assessments of the quality of all this individual work.

Making assessments

What was assessed. Over a period of 12 months we developed an assessment framework that allowed us to reflect an active model of technological capability. This model had three dimensions, concerning at its heart the **procedures** of designing and making (investigating, generating, making, evaluating etc). These procedures however are not there to be "seen" except through the medium of pupil drawing, writing, talking, modelling and making. You cannot see 'generating' without looking at drawing and modelling. Generating is a pupil *intention* that can only be interpreted - it cannot be directly observed in the way that 'drawing' can.

So the **procedures** of designing and the **manifestations** of those procedures form the first two dimensions of the framework, and these were supplemented by the third dimension - the **conceptual** understanding upon which the the designing depends, eg of users, of materials, energy systems, and aesthetics.

Having identified the elements of the framework however, it is vital to recognise that they cannot work in isolation. We were not interested in drawing skills for themselves - or abstract understandings about materials. There is a world of difference between on one hand holding a concept of electrical power or a skill in perspective drawing and on the other hand being able to **use** these understandings and skills to some purpose. And procedural, technological capability lay at the heart of the matter, for it is the driving purpose of the **task** that prevents conceptual understanding being merely intellectual detritus, and manifestation skills (eg drawing) being merely organ grinding (suitable for house trained monkeys). Totally incapable people (in technology term:) may hold a rich variety of conceptual understanding or communicative facility. It counts as nothing if the two cannot be welded together and used purposefully in a task.



Assesssment framework

It became ever more apparent that the relationships between these three dimensions of the framework were vital to capability, and yet we recognised that assessment strategies have traditionally divided them. Conceptual understanding has typically been tested in passive, written examinations and communicative facility through closed-ended drawing or practical tests of various sorts. For APU, the logic of our position forced us to reject this division and devise new approaches. Our view of capability demanded that we should not be interested in what students **know**, or what **skills** they possess, but rather in the extent to which both of these can be **used purposefully** in a task. All our tests were therefore task-centred and devised in ways that enable students (in a very short time) to get inside the demands of the task and display their capability in using and extending their understandings and skills.

Generating evidence. The first key to effective assessment is to ensure that there is adequate and appropriate *evidence* upon which to base judgments. This issue lies at the heart of test structuring, for the demands that are placed in the test are those that will provide the evidence upon which the judgments are to be made. It may help to have one of the tests unpicked - to see the range of evidence upon which it is possible to get some leverage.

The "Developing Solutions" tests were designed to examine how well pupils could develop and detail a solution - given a clear brief and a half developed 'concept model' of a solution. The test involved the following sub-tasks:

1 video contextualising
2 *introduction* to the task
3 jot down *early ideas* about the working of the concept model
4 list the *issues* that the final product has to address if it is to be successful
5 identify *strengths and weaknesses* in early ideas (in 3)
6 develop details and *working arrangements* of the product
7 identify the areas of function *still to be sorted out*
8 *review* the work in relation to the task as set (in 2)
9 identify the things that you need *to find out more about* to finalise the design

NB. the major blocks of time are in sections 3 and 6.

This test structure provides evidence of a wide range of capabilities and our approach to the assessment of these capabilities can readily be shown through sub-task 4.

*list the **issues** that the final product has to address if it is to be successful.*

In any design task there are a range of issues that bear upon the design solution and that can readily be categorised, eg....

safety
ease of use
aesthetic
packaging & marketability
cost/price
manufacturing & assembly constraints

Pupils are asked, in sub-task 4, to identify the range of issues that they see as being appropriate to their own early ideas for the solution. In their responses it is easy to see any bias that pupils bring to this sub-task. Typically they might prioritise ***either*** the human issues (ease of use & aesthetic) ***or*** the technical issues (manufacturing, assembly and technical function). It will not be difficult for the reader to predict the gender split of these characteristic positions. Capable pupils however, recognise the whole spread of issues and are able to scrutinise their product development through this diverse spectrum of concerns.

But we must remember that this is a ***performance*** assessment - not a memory test - so it is not good enough simply to list the issues and walk away. It would be all too easy to coach pupils into such responses. A key question therefore is whether - having listed an issue as important - they subsequently deal with it in their designing.

Mapping and judging. This sub-task 4 also illustrates another important principle of performance assessment - to do with the separation of what we came to term "mapping" from "judging". In the context of any particular task the list of issues that might be relevant is potentially very long - and we realised early on that it was quite inappropriate to use counting as a measure of quality. It was more important to ensure that the *spread* of issues was appropriate rather than to count the number. We therefore ***mapped*** the identified issues onto a matrix to ensure coverage and made a ***judgment*** about the spread in the context of the specifics in the task.

This same principle was used in all sections of the test. In section 6 for example - where pupils were developing the working arrangements for the product - we were very interested in the *modes of communication* that pupils used. Did they use orthographic or isometric or pictographic techniques, did they use notes and jottings, did they use formulae or any kinds of mathematical modelling, etc etc. Again, the list of techniques that they *might* have used is very long and none of them in itself is any sure measure of quality. It is none the less interesting to map what techniques they used whilst making a judgment about how well it enabled them to do what they were trying to do in design terms on the task.

The limitations of algorithms to explain performance. The foundations of our assessment policy were not imposed at the start, but grew out of our attempts to make effective assessments in each of the specific tasks. It became ever more evident that there was no simple relationship between things that can be ticked off from a list, and the judgments that we were making about the quality of the work. Sometimes a comprehensively ticked matrix would coincide with high quality work and sometimes it wouldn't. Sometimes a piece of work that led to a relatively sparse matrix would be independently judged by three assessors as of the highest quality. It became quite plain that performance assessment in technology cannot be left to the blind application of algorithms. At every level we came to the conclusion that such algorithms can be used to supplement and enrich judgments but not to make them in the first instance. It is clear that here are different ways of being technologically capable.

We were drawn to a position in which we had to reject the idea that judgments of overall technological capability can be aggregated up from smaller judgments. We were able to evolve an alternative strategy that was built on an initial holistic judgment of excellence followed by diagnostic teasing out of strengths and weaknesses. In each individual case the combination of strengths and weaknesses helped us to understand why the work was excellent, but there was no universal formula that worked reliably the other way around.

The outcome of all our deliberations was a three stage assessment regime.

step 1 The pupil's response was *judged* - holistically - on a 6 point scale of 0-5
step 2 The 14 major sub-sections of the response were *judged* on a 4 point scale
step 3 Descriptive matrices were compiled to *portray* the nature of the response.

Before committing ourselves to this policy, we explored in some detail the strategies and consequences of holistic assessment and - as a result - developed a comprehensive training schedule for markers. This involved analysing a selected variety of pupil work down to its constituent parts and putting it back together in a number of ways. We were able, in four regional one-day training sessions, to provide nearly 112 markers with the necessary understandings and experience to complete the exercise with good reliability. This was - quite properly - an area in which we were being particularly closely monitored by the Department of Education. The final reliability statistics show a median inter-marker correlation of .75 on the overview holistic judgment. (Kimbell et al 1991 p132 & appendix 9.3)

A Synopsis of Pupil Performance Data

It is almost impossible - not to mention misleading - to attempt to isolate individual influences on performance as there are so many and they are generally closely interrelated. When looking (for example) at gender effects on capability, it is very difficult to isolate it from the test structure effect, context effect, and task effect, not to mention the effects of ability and curriculum experience. Nevertheless, it is useful to tease these effects apart as far as possible, and having done so the following general trends emerge[13].

The test structure effect on gender groups. I have already indicated the importance of maintaining the balance between active and reflective elements of performance. Nevertheless, the organisation of the dominant domains of testing produced tests that were either broadly **reflective** or broadly **active**. In summary, Starting Points and Evaluating Products were dominantly reflective, and Developing Solutions and Modelling were dominantly active. The Early Ideas test is the most balanced of the test forms.

There is a remarkably close association between this analysis and the performance of girls and boys. Generally, girls do far better on the more reflective tests than boys, and boys do somewhat better than girls in the more active tests. In other words, **girls appear to be better at identifying tasks, investigating and appraising ideas, whilst boys seem to be better at generating and developing ideas.**

However, there are other factors about these tests that make this straightforward association a little less simple. I have outlined how the test structures can be analysed in terms of their procedural tightness. Broadly, if we divide the 90 minutes of activity into lots of 5 minute slots - each with a separate, but linked, demand - then the structure is very tight and leaves little room for pupils to organise the activity for themselves. By contrast, if we divide the 90 minutes into only 4 slots of 20 or 30 minutes, there is much more space in the activity for pupils to operate autonomously. This is a much looser structure. This was not something that we were consciously manipulating at the time, but rather something that we became increasingly aware of as we observed pupils doing the tests.

Interestingly, if we put the tests on a continuum of reflective/active, the order is paralleled by that for procedural tightness/looseness. Evaluating Products and Modelling are - on both scales - the extreme cases, and they reflect very closely the gender difference we outlined above. On the basis of our tests therefore, it is difficult to decide whether the gender effect is caused by the

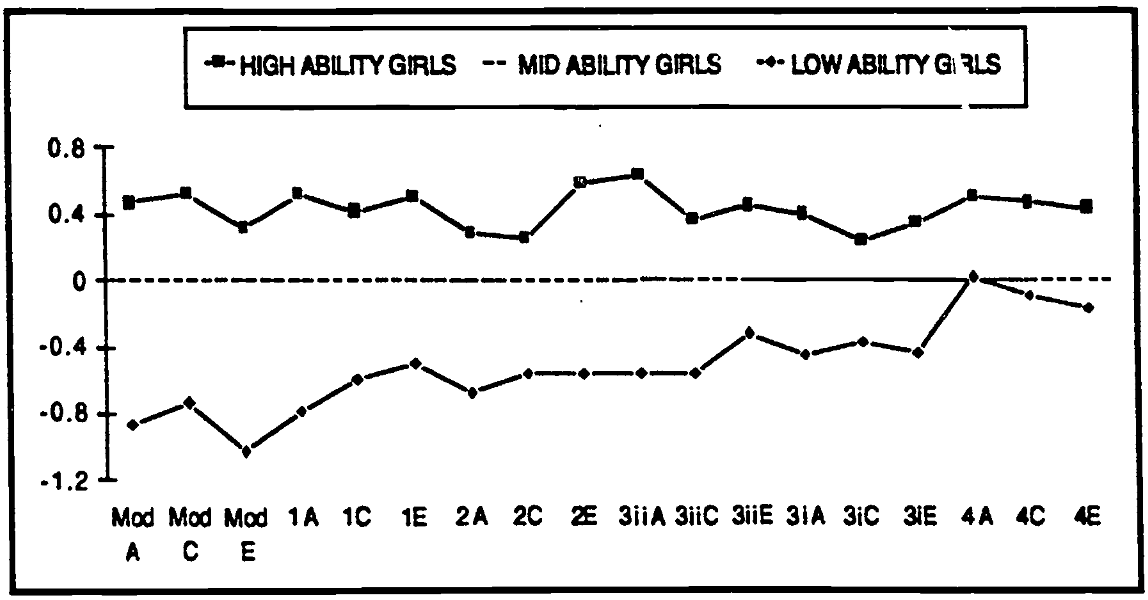
13 This section is a very brief summary of Section 15 of the full research report (Kimbell et al 1991)

reflective/active axis or the tightness/looseness axis - or by both. But whilst it is difficult for us to distinguish between (and quantify) these major influences, there can be no doubting that (either separately or together) they are having a serious effect on the performance of girls and boys. However, if this gender effect appears generally to hold true, it gets quite dramatic when the gender groups are split according to their general ability[14]. We start then to get an inkling of the relative importance of the two influences.

Adding general ability into the equation. The crucial issue here is the performance of low-ability pupils, and the ways in which the test structure (reflective/active and procedural tightness/looseness) influence these pupils. We should emphasise that these pupils are not necessarily poor performers in design and technology terms, but rather those judged unlikely to get many (if any) school-leaving examination passes.

A major pattern emerges in relation to the performance of low ability girls, certain test structures appearing to be far more supportive than others. The diagram shows the distance between the ability groups for their holistic scores. Because it is the *distance between the groups* that is of interest, the mid or average ability pupils are taken as the group against which the high and low ability pupils are measured and are represented by a zero score. The test structures have then been ordered by the relative performance of the low ability girls giving the Modelling tests (in which their performance is most depressed) at one end, and the Evaluating Products tests (in which they come closest to the other girls) at the other.

There is a clear effect at work here. As we saw above, the tests at the opposite ends of this chart are complete opposites in their structure; the Modelling tests being the most active and the most loosely structured, while the Evaluating Products tests (4A,C &E) are the most reflective and the most tightly structured. The combined effect on low ability girls is enormous. It is worth pointing out here also that tests 3i and 4 (where the low ability girls are performing at their best) provide the most concrete starting points for pupils - the 3i tests providing a 'concept model' of how an idea might work, and the 4 tests providing real objects to be evaluated.



The performance of girls in relation to test structure

14 We asked schools in the survey to supply a range of information on the pupils - including their "general ability" based on predictions of their performance in the school-leaving GCSE examinations.

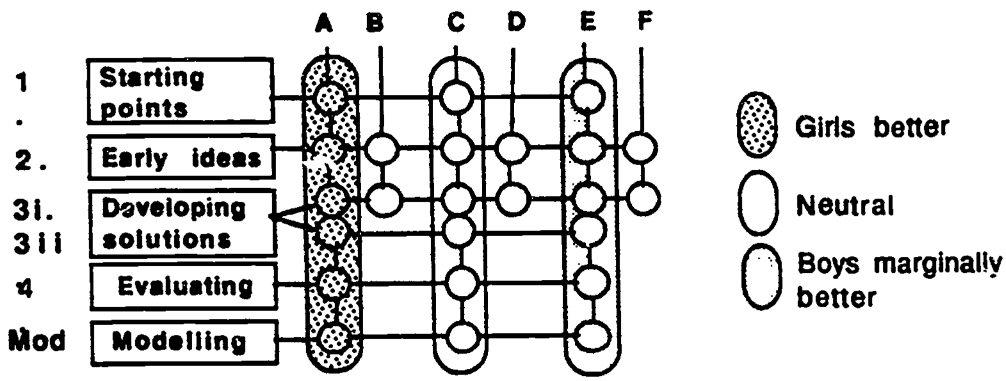
There are clear messages here about the sort of strategies that need to be adopted to help girls (and especially low-ability girls) to perform well in design & technology tasks. And the messages

are generally not about the **content** of the tasks but about the ways in which tasks are **structured** to support their performance.

In the case of boys, there is a different set of messages. If we examine the performance of high/mid/low ability boys on the same chart some quite obvious test structure effects emerge that are entirely consistent with our previous analysis of the effects of test structure, and it suggests that boys prefer a more open and active structure to activities. Such is the extent of the gender imbalance in the Evaluating Products tests, that the low ability girls almost outperform the high ability boys.

But a new factor enters the equation here as pupil performance varies considerably within test structures but *across contexts* and it is to this that we must now turn our attention.

The context effect on gender groups. Broadly speaking, the context effect is such that girls tend to out-perform boys in the contexts focused on *people* (eg. designing toys for children) whilst in the rest of the matrix the results are rather less clear cut. There is a tendency for boys to do better in the *industrial* context (eg designing for production), but this effect is heavily overlaid by the test structure effect discussed above. The context of *environments* (eg designing Post Office leaflet distribution system) would seem to be largely gender neutral.



Overview of the context effect on gender

In general, this effect appears to be acting both ways, such that the girls get worse in E and the boys get worse in A. Again however, the effect is more marked when the sample is split by ability, and the extreme cases of this are clearly observable in the low ability groups. If we look, for example, at the low-ability groups in Mod A, Mod C and Mod E we find girls performance dipping markedly in E and boys in A. This dip is of course relative to the mid-ability group and not necessarily an absolute difference. But when we examine the absolute figures we find a steadily increasing disparity across the three contexts.

Remember though that Modelling tests (being active and loosely structured) generally favour boys, and if we look at the reverse case in test 4 Evaluating Products, which generally favours girls, we find that exactly the same pattern appears in reverse. Here in context A the girls are much better than the boys whereas in contexts C and E the performance difference progressively reduces.

As a general rule it would appear that the context effect is less marked for higher ability pupils, suggesting - as one would expect - that more able pupils are less affected by the details of the task and are more able to generalise their capability.

The task effect on gender groups. I have explained how tasks can be located on a sliding scale of open-ness and closed-ness, and the more one moves through our test matrix from test 1 to test 4 the tighter the tasks become with proportionately less room for pupils to negotiate them for themselves and develop a sense of ownership. Generally, the more open the task, as in Starting Points or Early Ideas, the better the girls perform. Much tighter definition, as in Developing Solutions or Modelling, appears to favour boys.

However, this trend would be difficult to separate from the other general trends concerning the structure of the task, and there are instances where the general trend has been completely overturned . As we have seen, in context A, girls generally outperform boys - even in the tests where the structure of the activity is more supportive of boys (as for example in 3iA and Modelling A). How then do we explain the case of 3iiA, where the results suggest almost total dominance by the boys. In this case, the conceptual demands that are built into the task (prioritising mechanical systems) has seriously affected tne performance of gender groups.

The interacting effects on gender groups. It is difficult to tease apart the separate effects when in reality they all exist all the time in every test. Accordingly, performance in test 1A (for example) has a test structure effect favouring girls, a context effect favouring girls, and a task effect favouring girls. Not surprisingly the girls did very much better than the boys.

Conversely, in test 3iE, there was a test structure effect favouring boys, a context effect favouring boys, and a task effect favouring boys, and they accordingly did very much better than the girls. Wherever the effects that we have described above overlap and operate to the advantage of the same group, then we must expect that group significantly to outperform other groups. Only occasionally of course, do the effects all operate in the same direction. More often, if one effect operates in favour of one group this is balanced by a different effect favouring other groups. The total effect then is to reduce the gender bias in the results, and there is no significant difference in holistic performance between girls and boys.

One is led to the somewhat sinister conclusion that it would be possible - given an understanding of the nature of these effects - to design activities deliberately to favour any particular nominated group. More positively, it would also appear to be possible to design activities that largely eliminate bias or at least balance one sort of bias with another. It must be a matter of great importance for teachers to attain such a lack of bias (or at least a balance of bias) in designing tasks for pupils - or in negotiating them with pupils.

- Bear in mind that the **context** of the task will affect how it is received and understood - and particularly so in the case of lower ability pupils.
- Bear in mind that the details of the **specific task** - and particularly its 'open-ness' or ' closed-ness' , and the conceptual demands that it makes, will affect the ease with which pupils can deal with the task.
- Bear in mind that the **procedural structure** that you build into the activity, particularly the active/reflective balance and the 'tightness' or 'looseness' of the structure, will seriously affect pupils' ability to get to grips with the task.

The effects of curriculum experience on performance. By examining the pupil data from the survey it was possible for us to identify the curriculum followed by the whole test sample. We then used this to see to what extent - and in what ways - a background in Technology appeared to be supporting (or not) good performance.[15]

In relation to the **context effect** it would appear that experience of CDT tends significantly to reduce the variation in performance across context. Performance would appear to be much more

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15 The dominant technology experience in the curriculum at this time was CDT - Craft Design & Technology, and it is data in relation to this sub-sample that is referred to here.

consolidated and transferable. In 3iA (the people context), where girls tended to outperform boys, the boys who take CDT courses perform significantly better than the boys in the control group. Similarly, in 3iE (the industry context) where girls typically did not do well, the girls on CDT courses outperform the girls in the control group.

In relation to **test structure,** the effects of curriculum experience impact just as strongly. There is for example a tendency to reduce dramatically the gender effect that typically operates to the detriment of girls in 'open' and 'active' tests like Modelling and the CDT group in particular appear significantly to outperform the control group.

In overall terms, the CDT group consistently outperforms the control group. For boys, all categories of the assessment show better performance by the target group, and often it is a significantly better performance. Interestingly however, the strengths identified in 3iA appear as often as not to be greater strengths in 3iE, suggesting a robustness about their performance that carries them through the unfamiliarity of the context.

The situation for girls is only slightly different. Their out-performance of the control group is less marked than that of the boys, but the pattern across 3iA/E is almost identical to the boys. The pattern of performance is virtually identical across the two contexts/tasks

In the modelling tests, the general trend of the results again shows this group outperforming the control group. However by far the most startling aspect of these results concerns the performance of girls, who, especially in modelling test C, totally outperform the control and almost always (12 out of 17 categories) at a level of significance. In the principal assessment categories they **always** significantly outperform the control group and only in the less crucial areas is their dominance somewhat less marked.

One cannot help comparing these data with the 90 minute test data, for there we found that their out-performance of the control group was less marked than in the boys case. Here we find the reverse, with the CDT girls totally outperforming the control group. Whilst recognising that some of these data are from a different context (Modelling test C), it would appear that the modelling form of the tests has allowed the CDT girls to demonstrate far greater command of the task. There is a further points to be made here however, for not only do the CDT girls dramatically outperform their control group, but they also outperform the boys CDT group! This again flies counter to the bulk of the data which suggests that boys are generally outperforming girls in the Modelling tests. It appears not to be so when the girls have done a CDT course, which in turn suggests that girls benefit proportionately more than the boys from such courses. The strengths (dominantly **reflective**) that girls typically bring, when linked to a CDT course that typically (from the data) enhances **active** capability, creates a combination of strengths that allows them to achieve high levels of performance - which show up particularly well in our Modelling tests.

The Contribution of the APU Design & Technology Project

Influencing the form of NC Technology. In analysing the contributution of the APU project, one needs to remember the time frame within which it was set. As we were developing our assessment framework in 1986, the first moves were being made to draw up the National Curriculum. As we published the results of our pilot survey in 1987, the Working Party to define Design & Technology in the National Curriculum was deliberating and taking evidence. As we moved into our main survey in 1988 the Working Party produced its Interim Report. In looking for our contribution to the principles of assessment therefore one must first look to see how we influenced the writing of the Technology Order in the National Curriculum.

One does not need to look far. Our basic battery of 90 minute tests was constructed around a four stage description of the activity:

test one	Starting Points
test two	Early Ideas

test three	Developing Solutions
test four	Evaluating Products

The National Curriculum framework was based around four Attainment Targets;

AT1	Identifying needs and opportunities
AT2	Generating a design
AT3	Planning & Making
AT4	Evaluating

Established practice prior to the APU project would have centred on Designing and Making ie AT2 and AT3. It is likely that our work influenced this four AT structure, in particular in relation to the importance of the activity being *real* in the sense that it derives from a need or opportunity of a client group (ie AT1).

For example..

- We design a new leaflet dispenser for a Post Office not just because the teacher sets it as a task - but *because we have seen that current systems are patently failing.*
- We design a new storage unit for the pre-school play group not just because teacher says so - but *because we have seen that their current arrangement can be radically improved.*

As I have explained above, in our tests we had to made video to establish the reality of these tasks, but teachers are in a far stronger position to establish this reality. This is not to say that all activities must derive from needs identified by pupils - or that teachers must not set tasks. It is merely to point out that in *any* technology task (whoever sets it) pupils need to work out who the client is that they are designing for and what their priorities are.

Influencing the role of context. A further influence of APU thinking relates directly to this. Our tests (published in 1988) were contextualised through video, and we used six contrasting contexts within which we were able to establish dramatically different kinds of technology task. Prior to APU, little reference will be found in the literature to the role of context. The videos proved a great success with teachers, and not simply in terms of enabling them to run the tests. After the survey, we were inundated with requests for copies of the videos which teachers wanted to use as contextualising material for their normal technology projects.

In the following year, and perhaps not surprisingly, the NC Technology Order made the role and the importance of "context" quite explicit.

> We place much importance on pupils' design & technology activity being undertaken in a variety of contexts and specify what we have in mind by reference to home, school, community, industry.......(DES 1989 para 2.17)

There were at least two dimensions to this development.

1) Teachers were being encouraged to help pupils to derive design & technology tasks from the reality of their daily lives. This might not seem a particularly dramatic development - but it was in fact an enormous step to take. Whilst it would have been relatively commonplace in project work for 16 yr olds, it was unheard of for younger pupils and teachers found this adjustment very difficult.

2) The consequence of (i) above was that teachers found themselves managing lots of individual projects for younger pupils where formerly they would have set class projects. The problem that many teachers grappled with was how to construct a *teaching* course when the focus of projects was in the hands of pupils.

In reality the problem stemmed from a lack of preparation of the teachers for this radical development[16]. No one questioned the desirability of basing tasks in real contexts, but the only experience teachers had of doing this was the ways it is done for 16 yr olds where it was commonly interpreted as an open choice of project. There is no reason why this should work for all pupils - particularly when teachers want to use projects to teach particular things. In fact there is no contradiction between the teacher "setting" tasks and using real contexts.[17] If the teachers sets a task to do with designing a new house/environment for the class hamster or rabbit or the child's pet at home it can be a task that is suitable for all pupils - but which individuals can tailor to the particular interests/needs of their own pet. Such arrangements allow teachers to control the teaching agenda - whilst allowing pupils to personalise it to their own circumstances. The teachers can confidently introduce concepts of ergonomics - for example in relation to the size of the animal and its eating consumption - safe in the knowledge that it will be a common requirement even if Jane does keep rattlesnakes and Peter has a parrot. In many schools this good practice became the norm - but in too many schools teachers threw open the gates of choice, in effect abdicating responsibility for control of the teaching programme.

One of the legacies of the APU contexts therefore has been a heightened debate about the role of context in design & technology teaching. Contextualised tasks are patently a good thing - but they need to be managed with a degree of teaching subtlety that is not required when such contextualising is not seen as important. In practice, the debate has polarised performance; with the best teachers grasping the opportunities and moving forward with a new tool in their teaching toolkit, whilst others suffer disorientation in their teaching and then revert to more traditional safe practices. To support this debate, we produced a booklet for teachers[18] derived from our test programme and showing how contextual tasks can be *set* at different levels of specificity - allowing pupils greater or less room for manoeuvre in personalising the task. Contexts are enormously empowering for teachers and pupils alike, but they need to be used with professional care and expertise.

Establishing the iteration of action and reflection. Technology has for years suffered from an artificial separation of 'hand' work and 'head' work. As I pointed out earlier, one of the major elements in the success of the test activities we devised lay in our reconciliation of these two in ways that were mutually supportive. For example if you wish to evaluate the effectiveness of a product (essentially a 'headwork' task) we have shown that pupils can do it far more effectively when they link it to an activity that requires them actively to try to design a better one. The act of doing the active designing raises enormously the awareness of what is needed - and hence the level of reflective criticality that is applied to the existing product.

Such was the impact of this finding that it would appear to have had a major impact on the performance descriptors used in the NC Technology Order to define excellence. At almost every level in the Order, one finds performance statements that necessarily require pupils to integrate reflective with active performance. For example...

> level 2 (age 7)
> • Use pictures drawings, models to develop their design ....giving reasons for why they have chosen certain ideas *(action>>>>reflection)*
>
> level 5 (age 12)
> • Appraise the outcome in terms of the original need .....and how it might be improved *(reflection>>>>action)*
>
> level 7 (age 16)
> • Review the detail of their chosen design......and suggest alternative ways of achieving what is required. *(reflection>>>>action)*

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16 There was a very limited national In-Service teacher development programme

17 The APU tests alone should have shown this. The contexts were rich but the resulting tasks were very tightly structured.

18 "Negotiating Tasks in Design & Technology" HMSO 13744 SEAC 1991.

In all these cases (and many more), the requirement is to set practical action against thoughtful reflection, and this is the first time such balanced requirements have appeared in the assessment literature for design & technology. Teachers have responded very positively to this development. They have not only grasped the opportunity to improve their students performance but are also publicly delighting in the recognition that designing makes serious cognitive demands of pupils.

Expanding understanding about what is testable. The APU research exercise undoubtedly contributed to a transformation of opinion about the nature of testing in technology. The tradition of testing and assessment in technology has been that one can assess capability on extended projects (over several weeks) - and one can test knowledge and skill in short tests. Long-term project assessment however, has always been subjected to a number of criticisms; it is time consuming and expensive and without a lot of investment in cross-moderation processes it is not reliable for national testing. Inevitably therefore too much reliance is placed on the alternative mode - passive written examinations of knowledge.

The APU project provided an alternative. We established that it is possible to construct tests of *performance* and *capability* in technology that genuinely do measure how well pupils are able to make use of their knowledge and skills in tackling real tasks. And we were able to establish that these tests can be administered consistently and that the resulting work from pupils can be assessed reliably. It is not surprising therefore that when the Department of Education sought to establish NC tests for all pupils on a year by year basis, they commissioned this research group to the extent the messages of the APU project and create a set of tests for Technology in the NC at age 14. As it turned out, the advice we offered on the matter was not thought to be appropriate. Our work was suspended and developments took another course through a different agency. The subsequent collapse of the NC testing regime this year - in which the vast majority of teachers in the UK simply refused to administer them to their pupils - is now a matter of record. It is widely attributed to an ideologically driven anti-intellectual political agenda increasingly out of touch with the needs and aspirations of schools, and Technology was in the front line of this debacle. Whilst the ultimate revolt was significantly greater than anything one might have predicted, the limitations of the tests that were being imposed were manifest not just to researchers but equally to teachers and pupils.

As a result of this bruising experience, preparations for the further development of Technology and its assessment in the NC are entering calmer waters in which it would appear that research evidence will be allowed to make its contribution. It would be surprising if some of the more obvious issues to which this research project has drawn attention were not translated into the new generation of NC assessment strategies.

Understanding design & technology. Ultimately however, whilst this research project has been about assessment - its most enduring contribution will not (I predict) be about assessment. It will be in terms of the deepening of our collective understanding about the nature of the beast. As we pointed out in our conclusion to the research report;

> To tackle the assessment of performance one needs first to say what constitutes performance both in principle and in practice.....Accordingly we have embraced in our endeavour issues of educational principle and pedagogy and moreover we have sought to reflect these in our analysis and presentation of the resulting survey data. We would hope that teachers will see this as a curriculum research and development project as much as an assessment project. Indeed it is the first of its kind in design and technology. We hope that its results will be seen as much in terms of informing the nature of teaching and learning in design and technology as in providing base line data on pupil performance. In any case, the two are, as I hope we have shown, intimately related.
> (Kimbell et al 1991)

As I outlined in part 1 of this report, there continues to be a heated debate about the role and technology in the curriculum. Within this debate there are very few fixed points of reference to which one can appeal and one of these points of reference is the methodology and findings of the APU project. I believe it to be a realistic assessment that we have carried forward the debate about the nature of capability in technology and the contribution it can make to the development of young people.

This is the richest and most critical debate, and it is to the one to which we must now turn.

Learning through Technology

Three Models of Technology

There are several ways of looking at the nature of learning in Technology, and a useful approach is to analyse the experience in terms of the following three styles;

Awareness of technology

This involves a historical, sociological, economic, even philosophical study of the *impact* of technology over given periods of history. How (for example) did the development of bridge technology affect the placement and development of communities ? Why (for example) did the evolution of iron smelting take place where it did and how did it influence the development of society. Such studies are typically backward looking - reflecting upon what has happened in the past. The more adventurous courses of this kind seek to project forwards to *what might be* the consequences (for example) of global telecommunications, or non-intrusive surgery, or cars that can steer themselves from cables buried in the road. There is a massive literature to support such approaches, typically categorised as "History of Technology", and some very good materials have been developed specifically into course materials for schools.

These kinds of study do not require in-depth technological treatment as their priority is to contextualise technology into wider issues of human society. The common feature of these kinds of courses is that they treat technology as an accumulating set of magic "black boxes" - that can do clever things. In order to get started, you have to accept that satelites do x or that suspension bridges do y without really knowing (and perhaps without really caring) how.

Competence in technology

This is the absolute opposite of the 'awareness' course. It is essentially a 'hands-on' course that is not only designed to get into the nitty gritty business of how things work, but moreover is designed to enable course members to become competent in making them work.

This concrete focus almost inevitably results in highly specialised course structures. You can learn about - and become competent in - electrics, or mechanics, or lasers, or pneumatics, or integrated circuits, or programming, or whatever. Because of the depth of understanding and experience that is typically involved in such courses, there is not time to span very far across the field of technological endeavour. Courses are specialised and specific and lead to competent electricians or mechanics or programmers. Where such courses have been developed for use in schools (eg with 14 yr olds in the UK) they are almost always modular - with separate modules in a range of specific competencies.

If 'awareness' courses are a bit suspect in their grip on technological reality, then 'competence' courses suffer from the reciprocal difficulty. They tend to take for granted that technology is simply 'there' to be engaged in and - almost by extension - is inevitably therefore a good thing. Technology is not seen as a powerful influence on the structure of society - but rather as a branch of applied science.

Capability in technology

This is an entirely new phenomenon that is the outcome of three decades of development in the UK. It is not a passive intellectual study like the awareness courses, and neither is it a narrowly focused competence course. It is based on the *process* of design, development, manufacture and testing of new things; these 'things' being broadly categorised as products (eg chairs), systems (eg. of traffic flow) or environments (eg motor-home interior).

Competence courses typically focus on these classes of *outcome* and then generate bodies of knowledge and skill that surround them. Capability courses by contrast focus on the *process* of deriving outcomes and this process involves a unique blend of the intellectual and the practical.

In the first two of these schools of technological thought (awareness and competence) there is an obvious liaison to contrasted sectors of the curriculum. Awareness courses are the domain of the humanitarians who have no particular expertise in technology, nor (heaven forbid) any desire to acquire it. Such courses are for the thinkers and the policy makers who don't need to get their fingernails dirty.

By contrast, the competence course lies at the interface of the physical sciences with the workshop environment, and engineering is the dominant manifestation. Engineering courses are generally very content laden and specific (lighting engineer, heating , sound, mechanical, nuclear, aeronautical etc etc engineer). Whilst the traditional UK universities (for scholastic snobbery reasons) did their best to cleanse such courses of their practical workshop raison d'etre, the best courses are built around a tight integration of practice and theory.

But now we have a new beast - the capability course - that is designed not to replicate either of the former approaches, but rather to appeal to a quite new constituency. So where did it come from, what does it involve, and what qualities does it require and engender ? Whilst this new school of thought in technology in the UK has evolved from the former schools of thought largely through the innovation of teachers concerned with the *educational* significance of what they were doing, nevertheless - as we shall see - their efforts have subsequently been endorsed and supported by *industrialists* concerned about the kinds of new recruits they will need to survive in the marketplace.

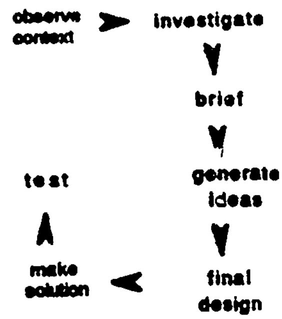
Technology as Thinking

There is an astonishing closeness between descriptions of the *process* of design & technology and the *process* of thought. This is so marked that there are areas where the two merge quite naturally. At the end of a very long treatise on "Thinking", Humphreys defines thinking as ..

> "what happens in experience when an organism, human or animal, meets, recognises, and solves a problem" (Humphreys 1951)

"Problem solving" gets the full treatment from psychologists seeking to describe and explain the processes of thought. Thomson (1959) outlines the characteristics of problem solving behaviour; Kubie (1962) relates it to the 'cybernetics' theory of learning; Vygotsky (1962) links it to the development of language and particularly to symbolic representation and Dewey (1910) relates it to schools and education. Normally - the argument runs - we don't think at all so long as things run smoothly for us. Habit, impulse and well practiced routine help us to drift through much work and play. It is only when the routine is disrupted by the intrusion of a difficulty that we are forced to stop drifting and think about what we are going to do.

The process is seen (broadly) as one involving problem clarification, investigation and exploration, analysis, creative attack, and subsequent re-evaluation. In fact it is - in generic form - the design process we examined in part one of this report. "Design methods" are operational models of thinking and if one takes away the specifics of materials and tools, then the intellectual process described on page 3 is an exact replica of the process of thought as described by Thomson et al.



The process of *designing* is a concrete manifestation of the process of *thinking*.

Designing is - in a sense - concrete thinking and it is no coincidence that in practice designers frequently talk of themselves as "thinking with a pencil", a quality that we explicitly encourage in young people in technology programmes.

This realisation has provided the central pedagogic underpinning that has carried forward the development of Technology in schools in the UK.

> From the simplest problem to the most complex, the design process is concerned with the educational problem of clarifying the thought process or 'reasoning' of the child, indeed it is an attempt to lay bare before the child his (sic) own thinking. (Kimbell 1975)

> The principal aim of Handicraft was the physical and emotional development of boys, mainly through the gradual acquisition of skills. Craft Design & Technology extends this to provide a fuller experience in which cognitive development features more strongly. Its central aim is to give girls and boys confidence in identifying, examining, and finally solving problems with the use of materials. (Department of Education and Science 1977)

Whereas the practical use of materials and the consequent development of motor skills had once provided the whole raison d'etre of workshop courses, in this new interpretation of Technology it became evident that a different kind of rationale was emerging; a rationale that saw materials and tools as the *vehicle* of learning rather than the purpose and point of learning. Whereas handicrafts had supported the emotional and physical development of young people, Technology was additionally demanding and encouraging intellectual growth.

The special feature of this encouragement is that - unlike so much of the curriculum - the processes of thought and decision making in Technology are exposed to the light of day. When you go through a design folder you can see the decision making unfolding before your eyes because the graphics, the models and the prototypes are clear concrete expressions of that thinking. There are several major consequences of this;

- you can go back over it with the pupil to examine where critical decisions were made
- you can look to see the basis of evidence for that decision
- you can examine points at which alternatives would have been possible
- and you can use these as jumping off points into new lines of development

In short Technology not only enhances the thinking and decision making powers of young people, it also enhances their *conscious awareness* of those thought processes. [1] They not only learn strategies of thought, they also know (and can see) that that is what they are doing.

And the final twist to this tale is that the pupil constituency to which this activity has traditionally appealed is not one that had held intellectual development at the top of its agenda. Before the implementation of the National Curriculum (which made Technology a compulsory study for all pupils) there was more than a fair share of difficult and disenchanted pupils in most Technology classes. They traditionally found refuge and strength in the practical orientation of the learning environment. For these pupils, technology has often been a transforming experience, not just because it kept them busy and out of trouble (which was often the rationale in craft courses) - but because it provides a concrete lever that can expose and get a purchase on their thought processes.

However, this opening up of the thinking and decision-making processes that pupils engage in in technology is clearly dependent upon a further factor. Thought (of any kind) is dependent upon language. As the philosopher Langer points out..

> Language of course is our prime instrument of conceptual expression. The things we can say are in effect the things we can think. Words are the terms of our thinking as well as the terms in which we present our thoughts, because they present the objects of thought to the thinker himself. Before language communicates ideas it gives them form, makes them clear and in fact makes them what they are. Whatever has a name is an object of thought.
> (Langer S 1962)

The Centrality of Communication

This view of the interdependence of language and thought[2] was seen by Langer to be about the use of words. Whilst I have no disagreement with the sense of what is proposed by Langer, Vygotsky et al , it is clear that the 'language' of technology is not - or at least not dominantly - words. It is *images* and *models* that are the central planks of thinking in technology. So Langer's idea has to be transposed somewhat...

> ...the things we can draw are the things we can think. Images are the terms of our thinking as well as the means by which we present our thoughts. .... before a model communicates an idea it gives it form and makes it clear . Whatever can be drawn and modelled can be an object of thought.
> ...
> (with apologies to Langer)

When trying to describe a complex three dimensional form, words are quite inadequate and images need to take over. Symbols (eg road signs) convey certain kinds of information far more quickly and efficiently than words can. If the reader needs any persuasion of this fact, try to describe in words how a door handle works - and then compare it to the ease with which one can describe the same thing diagrammatically.

This crucial relationship between a child's thinking and their ability to image & model lay at the heart of the APU project in Design & Technology.

> ..the act of expression pushes ideas forward. By the same token, the additional clarity that this throws on the idea enables the originator to think more deeply about it, which further extends the possibilities of the idea. Concrete expression (by whatever means) is therefore not merely something that allows us to see the designer's ideas, it is something without which the designer in unable to be clear what the ideas are..

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1 The term 'meta-cognition' has been applied to this phenomenon.

2 Vygotsky 's work here has been also highly influential

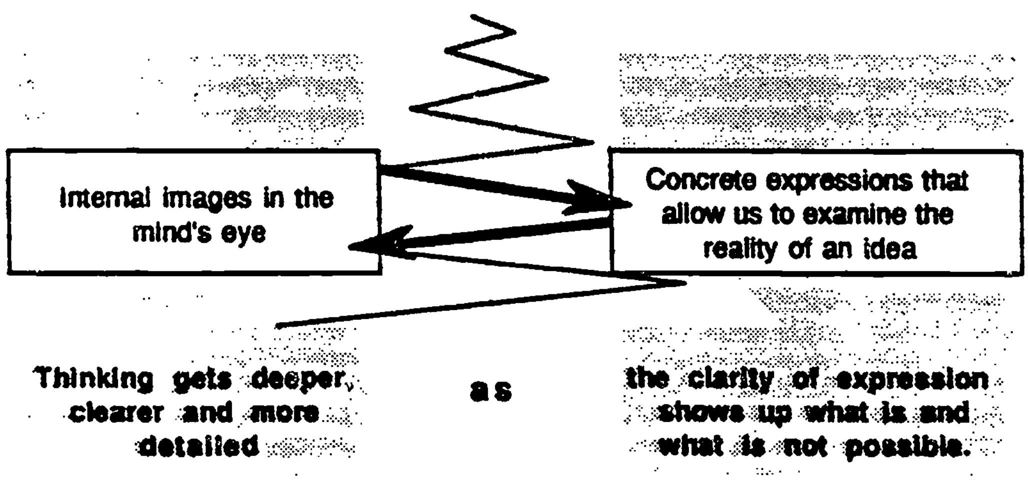
Cognitive modelling by itself - manipulating ideas purely in the mind's eye - has severe limitations when it comes to complex ideas and patterns. It is through externalised modelling techniques that such complex ideas can be expressed and clarified, thus supporting the next stage of cognitive modelling.

It is our contention that this inter-relationship between modelling ideas in the mind and modelling ideas in reality is the cornerstone of capability in design & technology. It is best described as "thought in action".
(Kimbell 1991 and 1991(b))

Nigel Cross, in his work at the Open University has similarly been drawn to the distinct language of technology. Having identified the mode of thinking in technology as 'constructive', he goes on to consider the 'codes' that translate abstract requirements into concrete objects, and the fact that we both 'read' and 'write' in these codes. He goes on to make a powerful case for technological activity in the curriculum largely on these grounds - that it enhances pupils ability to operate in the "iconic modes of cognition".

And these modes of thought are essential for all, not just for designers, as we all operate in a world in which object language is as vital as any other language. When we interact with objects (as opposed to abstract ideas) we need appropriate modes of communication. Imagine for example the difficulty of playing chess without a chess board. I know one or two people who claim to be able to do it - but most of us get along rather better (and are able to develop and think through more sophisticated strategies) when supported by the use of a concrete model - a chess board.

Thought and expression exists in a tight iterative relationship and this iteration was central to the APU tests that we developed. As I pointed out in part 2, the vast majority of tests and examinations in schools ignore this iteration where it bridges between the conceptual and the practical. Written tests allow pupils to grapple with ideas that are best expressed in words, whilst practical tests (in music, craft, and even science) typically confine themselves to the demonstration of skills that have already been mastered.



The iterative relationship between thought and expression

Neither of these forms of testing is suited to technology, where ideas conceived in the mind need to be expressed in concrete form in order for them to be taken further. The test forms that we eventually resolved for APU were in effect a manifestation of the iteration of thought and action described in the above graphic.

Knowledge and Technology

Whilst the teaching of craft skills has been a pervasive influence in the emergence of technology, the position and role of *knowledge* has only relatively recently come to be debated. And the ultimate question is what is it necessary to know before one can design and make things?

The first two schools of technology (the 'humanitarians' and the 'engineers') have, quite naturally, very different answers to this question. The engineers in particular will go on at length about all the branches of physical science that it is necessary to know. But we are interested here in the broader 'capability' school of thought - and the extent to which this capability necessarily entails knowledge about x,y, or z.

There have been plenty of warnings sounded about the dangers of being too prescriptive and heavy handed in technology.

> When there is a body of received knowledge to be acquired before speculation and imagination can be given free reign, then curiosity and enthusiasm will surely be quenched....It is most important not to equate intellectual rigour with excessive reliance upon the committing to memory of large quantities of factual information. (Dainton 1968)

More recently, and in the specific context of the development of technology in schools in the UK, the former Senior Staff Inspector for technology gets to the heart of the matter;

> Teaching facts is one thing; teaching pupils in such a way that they can apply facts is another; but providing learning opportunities which encourage pupils to use information naturally when handling uncertainty, in a manner which results in capability, is a challenge of a different kind. (Hicks 1983)

The difficulty in dealing with 'knowledge' in technology is to know what it is that you need to know. One task needs a quite different set of knowledge to another task. If I am to design a bivouac tent for mountaineering, I need to know about loads, structures, and temperature induced fatigue (in materials as well as in humans); if I need to design a lighting system I may need to know about low voltage electricity and switching systems. Moreover, it is not until I am half way into the tent task that I realise I need to know about the fixing conditions on rock faces, or the sheer load that can be borne by double stitching, or how the friction coefficient of the fabric changes with temperature. And if such information is not readily researchable, I need to devise a way of finding these things out.

> When embarking upon a new design, the package of knowledge and skills necessary for the success of the venture will emerge as the design progresses, and so the need to acquire knowledge and skills (and sometimes extend the boundary of knowledge and devise new skills) becomes a clear requirement for the designer (CNAA/SCUE 1985)

> The designer does not need to know all about everything so much as to know what to find out, what form the knowledge should take, and what depth of knowedge is required for a particular purpose (DES 1981)

For pupils to be effective in technology they need a cavalier approach to knowledge boundaries. They must at times be scientists (setting up experiments to find things out) , at times they must be social scientists (devising opinion questionnaires) , at times they must be good researchers (able to hunt out knowledge from books/databases/technical specifications) and - perhaps most critical of all - they must *at all times* be good at asking the right questions of the right people.

It is for these reasons that technology courses have been very cautious about trying to predetermine the body of knowledge that is a necessary pre-requisite of capability in technology. Almost every syllabus statement produced in the last ten years will have bold disclaimers ".....it is just not possible to define exactly what one will be required to know about in advance of the activity.. " (SEC

1985). And typically they then go on to outline the attitudes pupils need towards knowledge - and the strategies they need to learn to handle these "designerly ways of knowing". These strategies are always then presented in terms of liberal and flexible views of the nature and role of knowledge and emphasise the role of the teacher in supporting pupils in pursuing task-related knowledge for themselves.

> The recognision that new knowledge and skills are needed in order to continue is provoked by the questions that arise in their speculations, and the crucial role of the teacher at this point is in helping pupils to recognise and address these questions. The 'need to know' is the bridge which gves pupils access into the universe of external knowledge and skill and motivates them to proceed beyond their existing capabilities and resources. (DES 1987(b))

With ***knowledge***, the mark of capability in technology is not established by measuring how much of it pupils hold, but by seeing how effective they are in seeking it out in response to their task. And whilst the reasoning behind this development has been entirely driven by educational concerns, this is an area in which employers have wholeheartedly endorsed the development. There are few employment situations in which young people can simply apply what they already know. Far more frequently they need to be imaginative and resourceful in adapting and extending their knowledge to the immediate circumstances in which they find themselves.

Co-operative Learning

As I have outlined in section 2 of this report, the issue of collaborative working in technology is taking on ever increasing importance. We established, in the APU modelling tests that there is major benefit to be gained by pupils from sharing ideas at the development phase. The pupils' response to each others criticism was a major force in shaping the success or failure of their work. This is also a factor that has been identified in another technology initiative - TVEI - the Technical & Vocational Education Initiative launched by the Department of Trade and Industry in the early 1980s. This programme in particular recognised that it is only in schools where pupils are expected to spend all their time working on their own. In industry, teamwork is the norm. Whatever sector of business and industry you are in, tream work is typically at the heart of the working environment - production teams, sales/marketing teams, design teams, research teams, planning teams. Where are students to learn the skills of working in teams ?

The TVEI programme sought quite specifically to transform this view of learning as an individual activity and built its recommendations for practice around more collaborative approaches. The programme involved..

> a more practical, assignment led, group work pattern....

and one in which...

> the more relaxed relationship between student and teacher provided greater responsibility for students to be responsible for their own learning (Pring 1986)

Within the APU project we sought quite specifically to gather data about the effectiveness of team activities in technology. We were convinced from out own experience that children find it easier to make progress when they have the opportunity to use other people as a resource - as a sounding board against which to test ideas. But more than this, groups offer the opportunity to pool expertise and experience, and to draw on the individual strengths that individuals bring to the team.

I have described in part 2 the placement of the group discussion session within the heart of the modelling tests and the perception by the administrators that this had been helpful to many pupils. The pupil data supports this impression, for when we asked pupils to comment (in a post-test questionnaire) on the extent to which they found the discussions helpful in sorting out their ideas, the following responses emerged.

No help	8.6% of pupils
Some help	34.32% of pupils
Very helpful	56.21% of pupils
No response	0.85% of pupils
	total sample = 1288 pupils

Student responses with group discussion

Again, one has to be clear that there is nothing especially technological about this situation. I am confident that if pupils were given the same collaborative opportunities in a history project and then asked the same question, the same data would emerge. But technology does provide wonderful opportunities for collaborative approaches - and the models currently operating in industry provide concrete exemplification not only of the *need* for pupils to become familiar with this way of working but of the *benefits* that can accrue from it.

Values in Technology

But the central question about technology is still to be answered. We know - as teachers - that the core of the activity lies in the iteration of thought and action; that it has a particular language; and that it is parasitic on any body of knowledge that it might find useful. But we have yet to deal with the central question. Why do societies develop technology ? What is it all for ?

It is to do with the notion of improvement. The basic motive that underlies any technological activity is that we can intervene to modify and improve our environment.

> Among the multitude of animals which scamper, fly, burrow, and swim around us, man is the only one who is not locked into his environment. His imagination, his reason, his emotional subtlety and toughness, make it possible for him not to accept the environment but to change it. And that series of inventions, by which man from age to age has remade his environment... I call ... *The Ascent of Man.* (Bronowski J 1973)

Technology is by definition task centred, and results in some manifest change to the made world. The motive of "improvement" however naturally implies more than simply change. It imples change for the better, and this inevitably makes the concept of improvement somewhat problematic.

> Whether you see something as being 'better' will depend entirely on your value position. Is it 'better' to burn cheap fuels (based on hydro-carbons) or renewable fuels? Is it better to have motorways or the acres of open country that they use up? Inevitably design and technology impacts upon and is influenced by the political, economic, physical and social world in which we live and these influences create the climate in which some outcomes are seen as more desirable than others. (Kimbell et al 1991)

To engage in technology is to engage in a value-laden activity and - in an educational context - this makes it massively rich. Because the technologist is not merely a bystander in this value laden debate but has to find ways of resolving the conflicts that are an inevitable part of the technological endeavour. Shall I make it cheap (so that everyone can but it) or shall I make it so it will last a long time (so its good value for money) or shall I make it out of recyclable materials etc etc etc. The technologist has to optimise a solution to these dilemmas.

This balancing of value judgements defines the purpose of the task - conditions the way we resolve it - and ultimately decides whether or not others regard it as successful. In short values pervade technology.

For pupils in school, this is a seriously challenging position to be in. It requires them first of all to identify the value positions of those involved in the exercise - what would they see as a 'good' solution to this problem ? And knowing these positions allows one to sift the evidence in particular ways and develop a specification for a solution that is (as far as possible) agreeable to all parties. Once again, as in the question of language discussed above, technology provides concrete examples of social dispute. He wants it like this - but she wants it like that; this group's priority is to have it by next week - but if I do that I won't be able to .... This exercise is made even more difficult by the fact that we typically disguise our values and present them as facts. We commonly say "you can't have it like that" - when it would be more acurate to say "I would prefer you not to have it like that". Identifying values - and distinguishing them from facts is a key element in the development of capability in young people.

In the UK National Curriculum, these concerns are reflected in attainment statements described in the following terms. Can the pupil...

- recognise the points of view of others and consider what it is like to be in another person's situation.
- explain that a range of criteria which are sometimes conflicting must be used to make judgements
- understand that artefacts, systems or environments reflect the circumstances and values of particular cultures and communities.

(DES 1989) NB. these assessment statements apply to 12 yr olds.

Yet again one might argue that there is nothing especially technological about these qualities - and of course this would be true. But once again, whilst these issues might be shared by any activity in the curriculum, in technology they cannot be hidden in abstract debate - they are made manifest in real products that you can see, use, argue about, and seek to "improve". This concreteness is enormously valuable in giving young people access to issues that might otherwise pass them by.

Technology and Employment

It is a fact of life that there is perceived to be a direct link between technology in schools and subsequent industrial employment. Whilst it is acceptable that the school study of history should not be conditioned by the needs of that proportion of pupils who will become historians, in technology it is different. Even when (as in the UK currently) industrial manufacturing employment is small in comparison to other employment, the influence remains. And interestingly, over the last twenty years, there has been a sea change in the perceptions by industry of what it needs from its new recruits.

Reports addressing technology have focused on engineering priorities, and in a series of official Government papers, Swan (1968) Corfield (1976) Finniston (1980) and the National Economic Development Office/MSC (1984) castigated the constrained and knowledge focused nature of so much of the education of students for engineering.

- "First degree courses in technology are not sufficiently widely based to meet the needs of the individual and his (sic) employer"
- "The whole burden of developing competent engineers at present falls upon industry itself"
- "Complaints commonly voiced by employers are that the education of engineers is unduly scientific and theoretical"
- "Industry and Government need to insist on a more broadly based syllabus for engineering students".

It was against this background that technology courses in schools - of the kind outlined above - have developed, and increasingly they have been widely welcomed by industry. This welcome has been evident not just in their words of support, but more tangibly in their sponsorship of technology projects. BP for example are currently funding a major "Technology in Context" programme of teacher support specifically related to National Curriculum technology and a series of sponsors over a number of years (including Rolls Royce and GEC) has supported the Schools Design Prize (organised through the Design Council) and the Young Engineer for Britain competition (organised by the Engineering Council).

Many national figures - not least Margaret Thatcher - became great advocates for technology, one notable industrial leader, Sir Alex Smith, adding (in 1980) to the claims for technology to be a part of every child's curriculum.

> Every child in every school, every year, should be required to design something and make it...Education through designing and making is a basic need, even if our industries were blazingly successful, which they are manifestly not (Smith A 1980)

This trend is one that echoes very closely the SCANS report for America 2000 "What Work Requires of Schools".

> • good jobs will increasingly depend upon people who can put knowledge to work.
> • the most effective way of learning skills is "in context", placing learning objectives within a real environment rather than insisting that students learn in the abstract what they will be expected to apply.
> (SCANS Secretary's Commission on Achieving Necessary Skills 1991)

The report then goes on the outline the constituent parts of a foundation, more than half of which is made up of the following list:

- Creative thinking
- Decision making
- Problem solving
- Seeing things in the mind's eye
- Knowing how to learn
- Reasoning
- Responsibility and Self management

Given the 'fit' between this list and the qualities demanded and developed through a technological capability programme of the kind outlined above, it is not surprising that employers are warm to the products of these courses.

The days of industry requiring specific skill-trained employees are gone. And so too are the school-based craft programmes that once fed this employment. Technology as outlined here is not only seen by teachers as an educationally enriching experience for all pupils - and a necessary part of the compulsory curriculum - it is also sought out by employers as providing the levels of employee excellence that they need.

Conclusion

Technology in the school curriculum has grown from **practice** rather than from theory; from teachers in the classroom trying out innovative and often idiosyncratic activities and programmes - rather than from an intellectual analysis of a field of knowledge. And it has been hugely successful. Pupils voted with their feet; courses expanded and proliferated; competitions and prizes led to high profile public exposure where politicians and others were delighted to shake a few hands for the camera. Eventually, with the growth of Advanced level work, even the universities caught up with the fact that there were some quite exceptional young talents coming through this route and increasingly sought them out. As I hope I have shown, this growth has been steered by national projects, fostered by national initiatives and gradually been disseminated to a wide teaching force.

But the roots of its success lie in individual classrooms, studios and workshops where imaginative teachers sought to create not just a new subject - but a new approach to learning. Technology is now coming of age and has been made a compulsory study for all pupils. This process has required that it be tamed and institutionalised so that every teacher can cope with it and we should not be surprised when this process proves difficult.

It is difficult because ultimately technology cannot be defined in a body of knowledge and skills. It is better described as a set of ideals and processes into which pupils need progressively to be drawn. Naturally this induction relies upon the pupil developing knowledge and skill, but ultimately, pupils are not to be judged by their mastery of these skills so much as by their ability to recognise and grasp opportunities to change and improve the world through the exercise of their creative talents.

This was the big idea that Bronowski chronicled in *The Ascent of Man* and that lay at the heart of those pioneering courses in the 1960's and 70's. There is every reason to believe that it is an idea whose time has come.

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48

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49